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An Engineering Study of Onboard Checkout Techniques

FINAL REPORT

TASK 3: ONBOARD MAINTENANCE

Huntsville

IBM

An Engineering Study of Onboard Checkout Techniques

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FINAL REPORT

TASK 3: ONBOARD MAINTENANCE

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FOREWORD

This is one of a set of five final reports, each one describing the results of a task performed under Contract NAS 9-11189, "An Engineering Study of Onboard Checkout Techniques." The five reports are as follows, all dated March 1971:

- Task 1: REQUIREMENTS ANALYSIS AND CONCEPTS (IBM NO. 71W-00111)
- Task 2: SOFTWARE (IBM NO. 71W-00112)
- Task 3: ONBOARD MAINTENANCE (IBM NO. 71W-00113)
- Task 4: SUMMARY AND RECOMMENDATIONS (IBM NO. 71W-00114)
- Task 5: SUBSYSTEM LEVEL FAILURE MODES AND EFFECTS (IBM NO. 71W-00115)

The nine-month study was performed by the IBM Federal Systems Division at its Space Systems facility in Huntsville, Alabama, with the support of the McDonnell Douglas Astronautics Company Western Division, Huntington Beach, California.

Technical Monitor for the study was Mr. L. Marion Pringle, Jr., of the NASA Manned Spacecraft Center. The guidance and support given to the study by him and by other NASA personnel are gratefully acknowledged.

Section 1

INTRODUCTION

1.1 OBJECTIVE

The objective of the task reported in this document is to generate recommendations of supporting research and technology activities leading to implementation of a manned electronics maintenance facility for the Space Station.

1.2 TASK APPROACH

The task began with a review of the state of in-space maintenance technology, development of an approach to analyzing onboard maintenance requirements, and further definition of the key issues to be addressed. It soon became apparent that attention could not be confined to a central maintenance facility; it was necessary to refocus the task to address implementation of an onboard maintenance capability encompassing in-place as well as centralized maintenance activities. Because of budgetary and schedule limitations, it was necessary to continue to restrict the scope of the task to electronic equipment maintenance. The critical questions are the following.

- What is the optimum allocation of onboard maintenance functions between in-place and centralized maintenance facility locations?
- What is the optimum level of onboard repair (i.e., to line-replaceable unit, subassembly or module, piece part, or circuit element)?

1.2.1 MAINTENANCE CYCLE

In order to place the task in the proper context, a generalized Space Station electronic maintenance cycle is depicted in Figure 1-1.

A convenient place to enter the cycle is with detection of a fault ("In-Place Maintenance" block). The fault is isolated to a Line Replaceable Unit (LRU). The affected subsystem is restored to full capability by replacing the failed LRU with an operable one from spares storage.

The failed LRU is taken to a maintenance facility (assumed for the moment to have a fixed location in the Space Station) where it is first classified as repairable or non-repairable. Classifications will likely be predetermined, and a listing should be retained in the Data Management Subsystem. If the LRU is non-repairable,

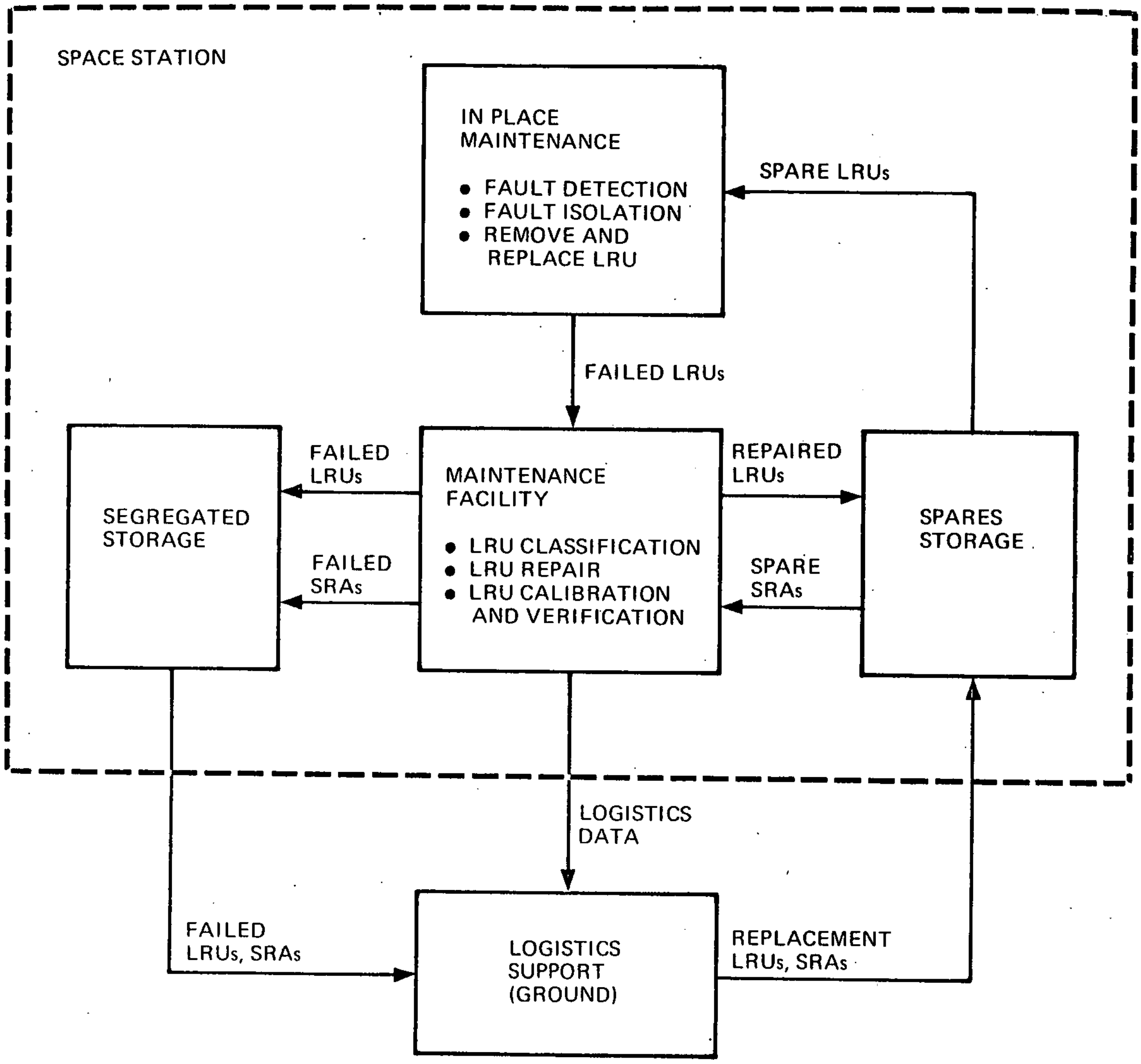

Figure 1-1. Space Station Maintenance Cycle

it is placed in segregated storage. If the LRU is repairable on board, the fault is further isolated to the failed Shop Replaceable Assembly (SRA). The LRU is then repaired by replacing the failed SRA with one from spares storage. The repaired LRU is then calibrated (if necessary), and its operation verified before it is placed in spares storage.

Logistics requirements (replacement LRUs and SRAs needed) are transmitted to ground-based logistics support functions by RF communications and/or Space Shuttle. Failed units are taken away from and replacement units are delivered to the Space Station by the Space Shuttle.

1.2.2 STUDY METHODOLOGY

The sequence of task activities actually followed in the study is depicted in Figure 1-2. Subtasks and activities are summarized below. Results are summarized in Section 2 and are detailed in subsequent sections.

- Maintenance Technology Review consisted of accumulation, review, and evaluation of the results of prior work in the field in order to avoid duplication of previous effort.

- Safety guidelines were adopted largely from previous work, primarily to assure that further analysis was appropriately constrained by safety considerations.

- A Sparing Philosophy aimed at providing spares at the lowest practicable assembly level, with maximum commonality, was adopted as a consideration in maintenance requirements analysis.

- Maintenance Requirements Analysis was the critical portion of the entire task. It consists of the following activities.

  - Establishment of a Data Base, consisting of information about three electronic subsystems, their LRUs and their SRAs, related to maintenance. These data are inputs to subsequent analyses.

  - Identification of Maintenance Techniques (Substitution, Direct Replacement, and Testing Fault Isolation) and their applicability to different maintenance approaches.

  - Analysis of Maintenance Incidents, or the frequency with which maintenance actions will be expected in each group of electronic equipment of interest.

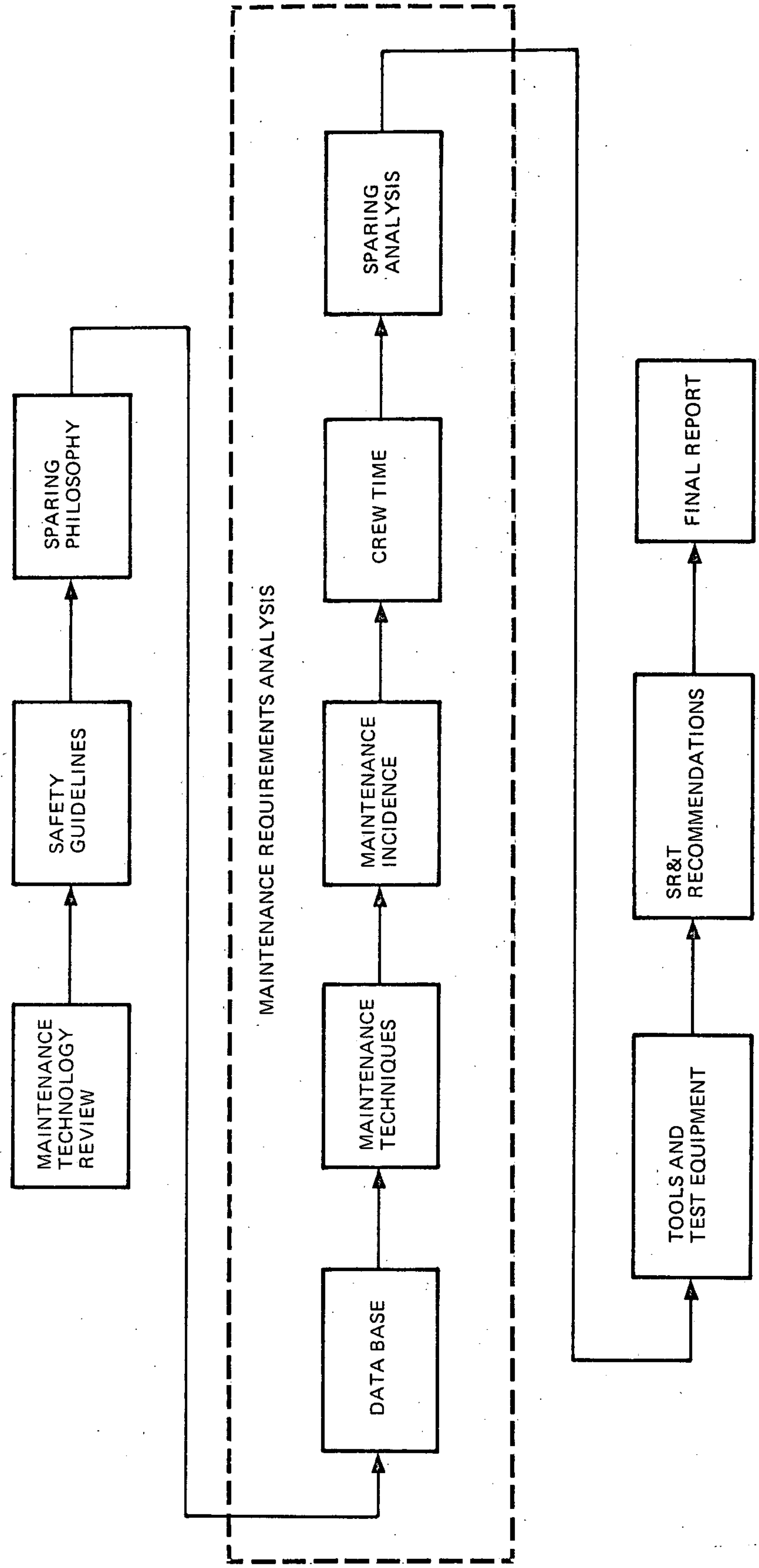

Figure 1-2. Task Activities

- Analysis of average Crew Time requirements to support fault isolation and maintenance for each maintenance concept of interest.

- Sparing Analysis consisted of estimating weight penalties associated with each maintenance concept.

- Tools and Test Equipment applicable to a Space Station onboard maintenance capability were identified to a level consistent with the level of definition of the prime equipment as it is presently known.

- Several candidate Supporting Research and Technology (SR&T) projects leading to implementation of an onboard electronic maintenance capability have been identified and summarized.

- This Final Report was compiled from the technical results of the foregoing activities.

Section 2

SUMMARY OF RESULTS

The study confirmed and emphasized the necessity of onboard maintenance for any manned mission of any complexity and duration measured in months (up to 10 years for Space Station). Formulation of recommendations for implementing such a capability required consideration of other topics first, and achievement of certain interim results. The principal conclusions of this study task are summarized in this section. The analyses leading to them are explained in subsequent sections.

- Prior studies and developments of in-space maintenance have emphasized justification of first-level (in-place) maintenance, fasteners, and tools for space application and human factors criteria. Much less attention has been devoted to test equipment, maintenance training, or definition of shop level maintenance requirements.

- The baseline subsystem descriptions, checkout requirements analysis, and software requirements analysis indicate that approximately 60 percent of all faults (over a long period) can be isolated to the failed LRU automatically under software control, without crew intervention. In an additional 27 percent of failure cases, fault isolation to one LRU can be achieved by the crew using the onboard Data Management System as a tool. In the remaining failure cases, additional fault isolation capabilities are needed. This is a good result for a "first iteration" and can probably be improved considerably with a modest effort to modify stimulus and measurement provisions.

- Crew involvement in scheduled and unscheduled maintenance (including participation in fault isolation) is estimated to average 7.2 manhours per week over the total mission time. This estimate is most sensitive to equipment reliability and levels at which onboard repair is performed. It is affected little by the efficiency of automated fault isolation under control of the Data Management Subsystem (DMS).

- The recommended approach to maintenance in the baseline Space Station is in-place removal and replacement of LRUs, without attempts to repair LRUs onboard, if the resupply interval is less than nine months. Onboard spares should be LRUs.

- For long resupply intervals or non-resupplied missions (as in a manned interplanetary mission), in-place maintenance should be by removal and replacement of LRUs. Repair of LRUs should be by removal and replacement of Shop Replaceable Assemblies (SRAs). Onboard spares should be SRAs.

- The Earth-orbital Space Station should include provision for development of onboard maintenance capability and techniques applicable to long duration non-resupplied missions and/or the larger, more complex Space Base.

- The baseline subsystem descriptions are at such a level of detail that precise specification of onboard tools and test equipment is neither feasible nor desirable. Anticipated needs identified qualitatively in the study are: (1) a portable test module to supplement software fault isolation as well as to assist mechanical adjustments and calibrator, (2) hand tools for removal and replacement of electronic assemblies, (3) devices for transporting and positioning spare assemblies, and (4) a central maintenance/repair bench.

- Several tasks have been identified and recommended for future performance, as part of a system study/design program or as separate supporting research and technology tasks. The principal ones deal with (1) development of a portable test assembly, (2) development of a repair/test bench with special provisions for small parts retention and for debris collection, (3) design for accessibility of test points and subassemblies, and (4) devices for transporting equipment within the Space Station.

The foregoing conclusions apply to the Modular Space Station as well as the 33-foot diameter, four-deck configuration.

The results of the study rest upon several assumptions and estimates, derived wherever possible from related experience. The results are not sensitive to small variations of the assumed or estimated values, except for equipment failure rates, which are most influential. Furthermore, it has not been practicable to pursue all trade analyses to include all relevant factors. Nevertheless, the study has generated valid insights into Space Station onboard maintenance and useful visibility of the path to implementation of that capability.

Section 3

MAINTENANCE TECHNOLOGY REVIEW

3.1 CONCLUSIONS

The Maintenance Technology Review included review and evaluation of 32 documents which from title and abstract appeared to address the topic of this study. Prior work has emphasized the following factors:

- Justification for first-level maintenance in flight
- Development and testing of fasteners and tools for use in the space environment
- Development of applicable human factors criteria

Little work has been done in

- Defining test equipment requirements
- Establishing maintenance training requirements
- Defining requirements for shop level maintenance

3.2 MAINTENANCE TECHNOLOGY REVIEW

Subsection 3.6 lists the documents studied to determine the status of development of in-flight maintenance concepts, tools, and test equipment. Information contained in the reports is divisible into four categories:

1. In-flight maintenance concepts
2. Tool and fastener design
3. Test equipment design
4. Human factors, documentation, and training requirements

Category 1 information was useful in formulating a sparing philosophy and defining safety guideline elements. Tool and fastener design criteria found in the category 2 reports are summarized. Category 3 information was negligible. Category 4 information is also summarized in the following subsection. This information provides guidelines and constraints useful to the overall maintenance facility concept.

3.3 IN-FLIGHT MAINTENANCE

Equipment to be maintained in space must be designed with maintainability in mind. At least two documents exist that will be of assistance to the equipment designer in this regard. The first and most recent is Appendix B of Reference (11) which is dated June 1970. The title is "Maintainability Design Criteria for Packaging of Space Replaceable Electronic Equipment." It is recommended that this document become a NASA standard and that it be made a contractual document in all Space Station hardware procurements where it is applicable. The second document is Reference (7) which was published in 1961. A portion of one of the tables in this document has been extracted, updated to the Space Station application, and included herewith as Table 3-1.

In-flight maintenance concepts appearing in the literature are oriented predominantly to in-place maintenance. Material applicable to a central Maintenance Facility is lacking, although some authors recognized other than first-level maintenance as a possibility (3, 21, 13).*

3.4 TOOL AND FASTENER DESIGN

Tool and fastener design data in the available literature are oriented to in-place removal and replacement. In general, existing tools are considered adequate and usable in the space environment. The major change recommended is increasing handles' sizes for EVA. Significant recommendations for fasteners and associated tools were made by three authors (11, 16, 19). Although the same conclusion was not reached as to the type of fastener recommended, the need for standardization of fasteners and their tools is widely recognized. Chapter 7, Appendix B, of reference (11), gives a good summary of the maintainability requirements for fasteners. Tool-operated fasteners should accept one of two standard sizes of internal wrenching hex drive. Reference (16) recommended no end loading type fasteners. Preference was given to a high torque fastener and tool made by Hi-Shear Corporation. Tests showed that the internal wrenching hex head fastener was subject to tool slippage with axial misalignment unless the socket is sufficiently deep. There is also a tendency to fumble when attempts were made to insert the tool if not perfectly aligned. This fault can be overcome by rounding

*Numbers in parentheses refer to items in Subsection 3.6.

Table 3-1. Maintainability Criteria for Space Station Crew Safety

Equipment/ Attributes	Line Maintenance	Shop Maintenance
Accessibility	Modules must be designed for quick easy removal and replacement. LRU must be designed such that replacement does not require removal or disconnection of another module.	Access to signal input and output points must allow for repair of modules or replacement of SRAs without major disassembly or removal of other components. Internal access must be considered from the bench check position of module. SRAs should not be placed so that the Astro-technician has to rely on feel.
Coding and Labeling	Replacement LRUs must be labeled, preferably on face of the LRU.	All SRAs and their positions must be identified.
Connectors	Must be reliable and capable of quick disconnect. Equipment should be shut down during maintenance to prevent arcing of connectors. Unique keys should be provided for a group of LRUs.	Crimp type connector pins should be used to facilitate maintenance.

Table 3-1. Maintainability Criteria for Space Station Crew Safety (Continued)

Equipment/ Attributes	Line Maintenance	Shop Maintenance
Controls	If adjustments are provided, they should be placed on the face of the LRU with positive covers to prevent accidental disturbing.	Internal controls to be adjusted should be accessible without SRA disturbance.
Displays	Should indicate malfunction to the LRU level.	Not applicable at this level of maintenance.
Fasteners	Must be quick and positive.	Must be positive and unaffected by handling.
Size	LRUs should be sized so they can be easily translated from place to place thru openings and ports by a single astronaut.	Provisions must be made so that both LRUs and SRAs can be handled. Handles should allow the module to be moved conveniently.
Shape	Shape of LRUs must be designed for ease of human handling in space.	SRAs must be of materials and shapes which can be handled. If not, special handling techniques or tools must be provided.
Standardization	LRUs must be sufficiently uniform for direct interchangeability without adjustment. LRUs should be functionally complete and functionally independent of other LRUs.	Standard symbols should be used for identification of SRAs. Standard and logical signal flow and circuit groupings should be used in design of modules.

Table 3-1. Maintainability Criteria for Space Station Crew Safety (Continued)

Equipment/ Attributes	Line Maintenance	Shop Maintenance
Test Equipment	Should indicate malfunction to the LRU level.	General Test equipment is most useful at this level.
	Reliability should exceed equipment reliability by a factor of ten.	Regular routine checks of equipment accuracies are required.
	Self-check features are required at this level of maintenance.	Final testing of LRUs must be dynamic and include capability to check anticipated system marginal conditions.
	Design of special test equipment must conform to Human Engineering requirements.	
	Malfunction indications must be unambiguous.	
	Each test function should indicate the module being tested.	
Test Points	Test points, if needed, should be on the face of panels and in accordance with Human Engineering principles for location, spacing, identification, etc.	Must be provided for signal input and output by SRA.
		Must conform to Human Engineering requirements for location, spacing, etc.
		Indications must be compatible with maintenance documentation.

Table 3-1. Maintainability Criteria for Space Station Crew Safety (Continued)

Equipment/ Attributes	Line Maintenance	Shop Maintenance
Tools	No tool requirements other than adjustment or remove and replace. Fasteners which require tools should be avoided if possible.	General bench tools usually adequate.
Mass	The mass* of the LRU must be within the ability of the astronaut to handle.	(Same as line maintenance.)

*60-70 earth pounds (R & M Trade-offs Tillotson (F) p. 4).

the tip of the tool so it can be inserted into the socket and then rotated until it slides into place. This author recommended the fluted or splined internal wrenching drive over the hex drive. It should again be emphasized that whichever fastener is selected for Space Station application should be used consistently throughout the Space Station with not more than two tool sizes.

Reference (19) included in the space tool kit such tools as screwdrivers, crescent wrenches, socket set, open-end wrench, and allen wrench sets. These could be reduced in number or eliminated by establishing a standard (two-size) internal wrenching fastener and tool combination for universal application throughout the Space Station.

3.5 HUMAN FACTORS - DOCUMENTATION AND TRAINING REQUIREMENTS

Several authors discussed human factors requirements, the most significant discussion being in document (11) which referenced in turn MSFC-STD-267A, Standard Human Engineering Design Criteria, revised in 1966. The other significant work in this area was reported in reference (25). Pertinent comments were:

- Keep clearances to walls and equipment to minimum distance to provide traction surfaces.
- Light, short duration tasks can be performed while free floating.
- Tasks requiring two hands or sustained force require restraints (foot).
- Seated in a chair with seat belt restraint, intricate assembly tasks can be performed.

Documentation requirements were also mentioned although briefly in most instances. The portable Astronaut's Test Kit (19) included a microfilm viewer and recommended that research be done to find or develop a flight qualifiable model. Reference (25) suggests that task procedures be thoroughly developed and rehearsed and that time lines be developed through task simulation. Reference (15) indicates that it is an advantage to prepare information in detail in the form of specially produced system diagrams, supported by monitoring, checkout, and setting up procedures in schedule form. The volume of maintenance data can be reduced by the following means:

- Tailor to needs of user.
- Emphasize brevity.
- Orient toward level of repairability.

Few of the sources reviewed mentioned training. One source was of the opinion that training was only necessary to implement the spares that were selected and carried onboard the Space Station.

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Section 4

MAINTENANCE SAFETY GUIDELINES

Design of all space-maintainable equipment must embody features for the protection of both personnel and equipment from electrical, mechanical, and thermal hazards. If an astronaut must divert his attention from his maintenance task in order to observe safety precautions, the remainder of his attention might be inadequate for doing his job well. If hazards cannot be completely designed out of space systems, it is imperative that those remaining be clearly recognized and that provisions be made to protect both the astronaut and the equipment against them.[11]

Most of the references reviewed addressed safety in general terms or in terms of the first level of maintenance. The most recent work in this area was done by Grumman Aerospace Engineering Company for MSFC[11]. Chapter 8 of Appendix B of this document adequately addresses safety during the first level of maintenance (Remove and Replace). Many of the guidelines for first level maintenance are also applicable to the second (Maintenance Facility) level of maintenance. The following discussion reiterates the discussion in the above referenced document where it is applicable to the Maintenance Facility, with added comments.

4.1 MECHANICAL HAZARDS

4.1.1 EDGES AND SURFACES

To minimize the possibility of physical injury, all edges and corners should be rounded to maximum practical radii. Thin edges should be avoided and construction should be such that the item can be handled without danger of cutting the space suit or the astronaut's hands. All exposed surfaces should be smooth, covered, or coated to prevent the possibility of abrasion. Small projections, especially in areas where rapid movement can cause injury, should not be left uncovered.

4.1.2 ROTATING DEVICES

The Maintenance Facility is being considered for electronic maintenance only, so this topic is not directly applicable.

4.1.3 EXPLOSION

Equipment that may be operated, maintained, or stored in an explosive atmosphere should be designed so as to eliminate the possibility of an explosion. All electrical equipment that will be used in the vicinity of flammable gases or vapors must be explosion-proof. Danger to personnel from an explosion should be avoided by separation of hazardous substances from heat sources and by incorporation of spark arrestors, suitable vents and drains, and other fire prevention measures.

An oxygen-enriched atmosphere presents another hazard to manned spacecraft. Maintenance disconnects, particularly electrical connectors, must be designed to prevent ignition of combustible materials in concentrated oxygen. The use of zero-g type connectors which break electrical leads in a confined cavity are not recommended in an oxygen-enriched atmosphere as the only means of preventing explosion and flash fire. The atmosphere in the Maintenance Facility must be controlled to the extent that it does not present a hazard. Second-level maintenance could involve probing with the lead of a meter or scope; thus, the potential for an arc is very real.

4.1.4 IMPLOSION

Direct view storage tubes and cathode-ray-tubes are special hazards in that physical damage can result from implosion of these devices. These tubes are replaceable at both the SRA and LRU levels. The hazard can be minimized by enclosing the tube and all its yokes, deflection coils, etc. within an implosion proof metallic container with a shatter-proof glass front. This metallic container would be the lowest level of replacement.

4.1.5 TETHER PROVISIONS

To prevent equipment from floating away under zero-g conditions, provisions must be made to tether the equipment being removed and the equipment to be installed. The tethering devices must:

- Be quickly applied (by using spring loaded snap fittings, for example)
- Be standardized throughout the spacecraft
- Be easily operable in both shirtsleeve and pressure suit environment
- Be designed to minimize interference with the astronaut's maintenance performance

4.2 ELECTRICAL HAZARDS

4.2.1 ELECTRIC SHOCK

The danger to personnel from electric shock must be eliminated by providing suitable safety interlocks and grounding enclosures or other protective devices plus a method of de-energizing power prior to making or breaking a connection. During IVA maintenance activity, some contact with electric potentials can be expected where personnel are, by the very nature of their maintenance duties, exposed to live terminals. Both shocks and burns, however, can be eliminated by exercising care in design and by a thorough understanding of electrical power characteristics.

4.2.2 PREVENTION OF ELECTRIC SHOCK

Provisions must be made to protect both personnel and equipment during manual fault isolation to the SRA level. Power down procedures before remove-and-replace action should eliminate shock hazards during this operation. Typical ways of providing shock protection are listed below. The methods selected will depend on the voltages involved, the type of mounting, and the electrical interface used:

- Design so exposed voltage terminals are not located in the vicinity of test points
- Protective plastic covers over exposed potentially hazardous voltages
- Eliminate probing as a troubleshooting technique

4.2.3 ARCING

Recommendations for "dead facing" and "down powering," if followed, will eliminate the arcing problem during first-level maintenance and hook up of LRU in the maintenance facility. Down powering should become a standard procedural step before the SRA is removed and replaced. To prevent arcs during troubleshooting procedures, probing must be eliminated as a troubleshooting technique. This imposes the requirement on design to provide adequate test points in a test connector that can be wired into appropriate test equipment.

4.3 SAFETY MARKINGS

Markings should be provided to warn personnel of hazardous conditions and precautions to be observed to ensure safety of personnel and equipment.

Warning signs marked "CAUTION-HIGH VOLTAGE" or "CAUTION-HIGH VOLTS" should be placed in prominent positions on safety covers, access doors, and inside equipment wherever danger might be encountered. These signs should be durable, easily read, and placed so that dust or other foreign matter will not, in time, obscure the warnings. Because signs are not physical barriers, they should be relied on only if no other method of protection is feasible.

The predominant color of equipment designed for safety, protective, or emergency purposes should be Insignia Red, Color No. 11136 of RED STD 595.

4.4 THERMAL HAZARD

Shields and guards must be used to prevent personnel from accidentally contacting items that are either hot or cold enough to cause personnel injury. Gloves or other protective clothing must be worn when it is necessary to perform maintenance in close proximity to hot or cold equipment such as Life Support water storage tanks during sterilization processes or cryogenic tanks, lines, and fittings. This should not be a problem in the Maintenance Facility.

Section 5

SPARES PROVISIONING PHILOSOPHY

5.1 GENERAL

Adequate spares must be carried onboard the Space Station to assure that crew safety and mission success are not endangered for lack of a spare. On the other hand there are weight and volume constraints that must be considered. Providing all the spares that appear to be required may incur severe payload penalties. A desirable future task is to select or generate a computer program that will determine adequate spare quantities based on all the limiting parameters, such as, cost, weight, volume, resupply interval and maintenance level.

Another important factor is commonality. The number of different types of modules, whether at the LRU level or SRA level, should be minimized. Prior experience in space equipment design has indicated a tendency to sacrifice commonality in favor of other design parameters. One author identified some of the possibilities of designing common modules which are interchangeable. An excerpt from this article (31) follows as Subsection 5.2.

Criticality of the subsystem or portion of the subsystem will have a direct bearing on the criticality of the spare line replaceable units (LRU). Ordinarily it will be desirable to restore the failed subsystem as quickly as possible so the repair action will take place by removing the failed LRU from the subsystem and replacing it with a spare LRU from serviceable storage. Some disposition is then made of the failed LRU. It is conceivable that some subsystem element might be of sufficiently low criticality or duty cycle that it will be more desirable to spare only at the shop replaceable assembly (SRA) level. In this situation the faulty LRU would be removed from the subsystem and taken to the Maintenance Facility where it would be repaired by removing and replacing the faulty SRA. The now refurbished LRU is then placed in the subsystem to restore it to service. At the other extreme is the subsystem that is so critical that the failure can hardly be tolerated. In this situation, switchable redundancy will be used. If very critical, the circuitry should be designed for automatic switching with an appropriate signal to the control and display function that the switching had occurred. Then a normal remove-and-replace action would ensue to restore the subsystem's redundancy at the earliest convenient moment.

Sparing at the SRA level is desirable for the following reasons:

- Reduce the number of complex LRUs that are required on board, thus reducing weight and required storage volume.

- Decrease the level of diagnostic resolution required. There would be a trade-off here between instrumenting for automatic fault isolation on-line, and providing off-line (Maintenance Facility) fault isolation capability. (i.e., the LRU would be a more complex, larger unit due to earlier termination of automatic fault isolation.) The subsystem could be restored to service by replacing this large block of circuitry; then the LRU would be tested and repaired in the Maintenance Facility when more time was available.

5.2 INTERCHANGEABILITY*

5.2.1 POTENTIAL

Items which have interchangeability potential are numerous and are limited only by the spacecraft designers' imagination and resourcefulness. The following is a partial list of candidates:

- Relays
- Switches
- Logic Modules
- Memory Units
- Power Supplies
- Oscillators
- Discriminators
- Amplifiers
- Buffers
- Instruments
- Lighting
- Blowers
- Pumps
- Motors
- Heat Exchangers
- Check Valves
- Shut-off Valves
- Heaters
- Thrusters
- Water Separators

* Reference 31, Subsection 3.6

5.2.2 MODULARIZATION

Interchangeability need not be restricted to an equipment level. For instance, solenoid-actuated mechanisms may be designed to use a common solenoid. In this case, the solenoid could become the replaceable part level instead of the solenoid-operated device. Modularization should be utilized to the maximum extent possible. There may be motor applications where each application requires a different size motor. Using the modular approach, it may be possible to use one motor for an application, or two or more motors in tandem, where more power is required.

Heat exchangers can sometimes be modularized. Two small ones might be operated together to provide the function of one large one. Many instruments on a panel contain the same basic mechanism, differing only in their dial faces and range markings. Separating the mechanism from the dial face provides for an interchangeable instrument module.

Many logic modules differ from one another only in one or a few of the many components installed in the module. Interchangeability can be achieved by providing for replacement of the differences, providing extra components so that modules can work in many applications, or by packaging so that the differences form a separate module, thereby maximizing the interchangeability of a large percentage of the components of the module.

5.2.3 LEVEL OF MAINTENANCE

The designer should not limit his thinking to any specific level of interchangeability. The level of maintenance selected for in-flight maintenance must be kept flexible-dependent only on the fault isolation capability, the ability of the crew to perform the maintenance task, and the extent of repeatability of the parts required to perform the task. The level of maintenance can be at the assembly level, the subassembly level, or the piece part level. Selection of the level of maintenance must be made on an individual basis; no one level fits all situations.

Section 6

MAINTENANCE REQUIREMENTS ANALYSIS

6.1 DATA BASE

A matrix form was developed for conducting a maintenance requirements analysis (MRA) and to accumulate pertinent data for the Data Management; RF Communications; and Guidance, Navigation, and Control Subsystems. Available Space Station Phase B design data are not in sufficient depth to directly provide all of the data needed to complete the matrix. In some instances (especially with respect to listing SRAs), it was necessary to make assumptions and estimates based on related experience and reasonable extrapolations of technological growth. The results of this data-tabulation activity appear in Appendix A. This information was used in subsequent analyses.

6.2 BASIC CONSIDERATIONS

6.2.1 MAINTENANCE CAPABILITY

The primary purposes of the Maintenance Facility task were to provide a definition of a maintenance capability for the Space Station and to consider the maintenance capability requirement unique to long duration, non-resupplied missions. The objective of the study is therefore described as the definition of an onboard maintenance capability as distinguished from the definition of a centralized Maintenance Facility. Maintenance capability includes tools, test equipment, accessories required for holding and maneuvering spare assemblies and test equipment, documentation, documentation retrieval, display facilities, and crew skills. It also includes the use of control and display equipment, checkout system, DMS software, and a centralized maintenance facility if required.

6.2.2 BACKGROUND

Traditionally, on-line (in-place) maintenance consists of the following elements:

- Preparation
- Fault Isolation
- Access
- Removal and Replacement

- Close-up
- Adjustment/Calibration
- Verification

Up to 80 percent of the total maintenance time has historically been used in isolating the fault to an assembly that was small enough to be replaced to get the equipment/system back into service. For many years the replaceable element was the lowest level possible, the nonrepairable piece part. Efforts to reduce maintenance time resulted in equipment modularization. This introduced a shop maintenance requirement where the fault within a module could be isolated and the faulty piece part removed and discarded. Soon even this activity was greatly curtailed, and the replaceable modules were returned to a central depot where the volume of repair activity was large enough to justify the expensive diagnostic equipment that was needed. In addition, a technician could become experienced and skilled enough to deal with the highly complex fault isolation process.

Improvements in technology have reduced the size of many modules and integrated many functions into elements that are no longer individually replaceable, raising the throw-away element to a higher functional level. The growth of system technology demanded that help be given to the maintenance technician if the system, or the equipment, were to be operable a sufficient amount of time to justify its existence and make it possible to perform the tasks it was originally designed to perform.

Part of this help came in the form of higher reliability designed into the elements that made up the system. Another contribution was the development of self-monitoring and diagnostic routines that reduced the fault isolation time requirement and made it possible to find faults that previously were nearly impossible to isolate. Further contributions were made through the development of maintainability concepts which stressed accessibility and replaceability of the system modules.

6.2.3 RESOURCES AND EVALUATION CRITERIA

Effective onboard maintenance will contribute greatly to sustaining full operational capability in the Space Station in return for nominal use of available resources: DMS services, crew time, electrical power, weight, volume, and cost. Alternate maintenance concepts can be rated relative to each other on the basis of their consumption of these important resources.

The Data Management Subsystem will be used for automatic control of fault detection, fault isolation, and automatic reconfiguration. Ideally, every fault will be traced automatically by the DMS to the Line Replaceable Unit (LRU) in which the failure occurred, without crew intervention or interplay with the DMS. It is unlikely that the ideal will ever be achieved, although it can be approached closely for a corresponding increase in software cost. The preliminary results of other study tasks have been used to derive the following rather pessimistic estimates.

- Sixty percent of all electronic failures will be isolated automatically under DMS control to the faulty LRU without crew participation.
- Twenty-seven percent of all electronic failures will be isolated to the faulty LRU by the crew, using the DMS as the diagnostic tool.
- Thirteen percent of all electronic failures will be isolated to the faulty LRU by the crew, first using the DMS to isolate the fault to a group of LRUs and then using other means to complete fault isolation.

The use of the DMS as described above is common to all maintenance concepts considered by this task. Its effectiveness in fault isolation is one of the factors contributing to the amount of crew time devoted to maintenance.

Crew time is a resource of particular importance to achievement of primary mission objectives, and the amount of time needed for maintenance should be minimized. This is especially true of the Modular Space Station.

Power, weight, and volume in electronic systems exhibit a strong correlation, depending on the amount of equipment provided. For the purposes of this study, it was sufficient to concentrate on weight, taking all the following into account.

- Subsystems, including in-place redundant elements
- Spares
- Tools, test equipment, and maintenance aids, including manuals

Cost of onboard equipment will be strongly correlated with the complexity (hence, weight) of that equipment, but is not readily quantifiable. This is even more true of the less obvious elements of program cost such as ground support equipment, personnel, and software. The cost of maintenance training of crew members can only be expressed in relative terms.

6.3 MAINTENANCE CONCEPTS AND TECHNIQUES

The two questions that are fundamental to definition of a maintenance approach are:

- Where will maintenance be performed?
- To what level will unscheduled maintenance be performed?

6.3.1 LOCATION OF MAINTENANCE ACTIVITY

The study considered two locations in the Space Station for performing maintenance: in-place and in a central facility. Both unscheduled and scheduled maintenance actions have been considered. Unscheduled actions include fault isolation, repair, and verification. Repair may be limited to removal and replacement of a faulty unit or it may include physical repair of an assembly. Scheduled maintenance actions include preventive maintenance, calibration, and pre-installation checks.

The number of ways maintenance actions can be assigned to the two locations is very large, but most combinations are illogical. To provide a reasonable basis for conducting the maintenance capability study, the four most appropriate approaches for accomplishing maintenance on the basis of location were identified as shown in Table 6-1. The two most suitable approaches were then selected, one for in-place maintenance and one for centralized maintenance.

Total in-place maintenance was considered first. This approach seems feasible for all actions except physical repair, provided the disruption of subsystem operation due to maintenance activities can be tolerated. It was concluded that repair activities, especially repairs that could contaminate the environment through residue such as wire scraps, solder, or the release of gases, should be performed in a controlled environment. Approach number two was therefore selected as the in-place maintenance approach.

Table 6-1. Maintenance Action Allocations

		Maintenance Approach			
		1	2	3	4
Unscheduled	Isolation	I	I	I	C
	Repair	I	C	C	C
	Verification	I	I	C	C
Scheduled	Preventive	I	I	C	C
	Calibration	I	I	C	C
	Pre-Installation	I	I	C	C

I = In-place C = Central

Two levels of centralized maintenance were considered. Maintenance approach No. 3 is a totally centralized maintenance approach with the exception that isolation of faults is performed in place. Approach No. 4 requires that all manual maintenance actions be performed in the central facility. The capability to verify faults in a central facility will also include the capability for isolation of faults. Therefore, the selected centralized approach was the one that required all maintenance actions to be performed in the central facility. This means that fault isolation would be performed in place up to the point where crew intervention was required. Removal and replacement would be performed at the isolatable level. All other maintenance activity would be performed in the central facility.

The need for a central maintenance facility depends upon selection of the hardware level (SRA or LRU) at which repair is to be effected.

6.3.2 REPAIR AND REPLACEMENT LEVEL

There are three basic techniques applicable to electronic maintenance in the Space Station. They are:

- Substitution of a good LRU or SRA for one which may be faulty (i.e., one of a group to which a fault has been isolated).
- Direct Replacement of an LRU or SRA known to be faulty with a good one, after fault isolation to the appropriate level.
- Use of a Test Interface and special test equipment for fault isolation not achievable by the DMS or by substitution.

The applicability of each technique depends upon the choice made from the following options:

- Repair action by replacement at either the LRU or SRA level.
- Fault isolation by the DMS, with or without crew participation to (1) a group of LRUs, (2) a single LRU, or (3) the faulty SRA within the faulty LRU.
- SRAs either pluggable or non-pluggable (welded or soldered in place) within the LRUs. A mix of pluggable and non-pluggable SRAs is also an admissible option. All LRUs are pluggable.

The maintenance techniques and options are interrelated as shown in Table 6-2. Direct replacement is required in every instance for completion of repair action. Substitution applies where DMS/crew fault isolation does not extend to the replaceable device, except for non-pluggable SRAs. A test interface (for use of additional test equipment) is needed when (1) DMS/crew fault isolation does not extend to the replaceable and (2) fault isolation by substitution is not permitted. Where the replacement level is SRA, the capability of fault isolation to the LRUs is necessarily presupposed.

An elementary evaluation has been constructed and is shown in Table 6-2, based on six categories of resource requirements. The scoring system is based on a minimum of 1.0 (least advantageous) to a maximum of 6.0 (most advantageous). When an approximate "tie" exists, scores are adjusted so that for each row the total is 21.0. Given more time to pursue the evaluation in depth, with more detailed definitions of evaluation criteria and assignment of weighting factors, a different order of preference may result. But it is most likely that fault isolation and repair by replacement at the LRU level would still emerge as the preferred approach.

6.4 LRU REPLACEMENT ANALYSIS

This subsection will analyze the maintenance concept centered around repair by replacement at the LRU level. SRA level replacement will be discussed in Subsection 6.5.

6.4.1 MAINTENANCE INCIDENTS

The number of maintenance incidents over a long period of time is a function of the mean-time-between-failure (MTBF) estimated for the various LRUs included in each subsystem. As shown in Table 6-3, over a period of 180 days, the unscheduled maintenance incidents were 23 for the DM, 3 for the GN&C, and 2 for the RF Communication Subsystems. These subsystems were considered to comprise 80 percent of the total electronics in all subsystems. The result is an estimated total of 35 electronic assembly failures in a period of 180 days. The computation method is illustrated by example in Table 6-4.

Scheduled maintenance incidents including preventive maintenance, calibration, and pre-installation checkout, were estimated to equal unscheduled maintenance incidents. The 1-to-1 ratio is based on records of scheduled and unscheduled maintenance incidents occurring in commercial installations having similar functional capability.

The scheduled incidents could be distributed over in-place and centralized maintenance facilities. The unscheduled maintenance incidents, however, could not be so distributed.

Table 6-2. Maintenance Concepts and Techniques

Replacement Level		LRU		SRA			
Isolation Level		Single LRU	LRU Group	LRU		SRA	
Mounting Provision		Pluggable	Pluggable	Pluggable	Non-Pluggable	Pluggable	Non-Pluggable
Technique	Substitution		X	X			
	Direct Replacement	X	X	X	X	X	X
	Test Interface		X	X	X		
Resource Requirements	Crew Time	6.0	5.0	2.5	1.0	4.0	2.5
	Crew Skill	6.0	5.0	3.0	1.0	4.0	2.0
	Subsystem Weight	4.5	4.5	1.5	4.5	1.5	4.5
	Spares Weight	1.5	1.5	3.5	5.5	3.5	5.5
	Tools and Test Equipment	6.0	5.0	2.0	1.0	3.0	4.0
	DMS Software	4.0	6.0	4.0	4.0	1.5	1.5
Score		28.0	27.0	16.5	17.0	17.5	20.0

Table 6-3. Maintenance Incidents

Subsystem	Incidents per 180 Days Unscheduled (1)	Incidents per 180 Days Scheduled (2)
DMS	23	23
GN&CS	3	3
RFCS	2	2
Other	7	7
Total	35	35

Total incidents per 180 days = 70
Average incidents per day = 0.4

NOTES:
(1) Based on LRU reliability estimates.
(2) Based on ground maintenance experience of one scheduled maintenance period per one unscheduled maintenance period.

The minimum average number of in-place incidents per day would be 0.2, and the total incident rate of 0.4 per day would be distributed according to the selected maintenance approach. The number of incidents is somewhat independent of the level of replaceability because it is based strictly upon the reliability (MTBF) estimated for the subsystems and upon an assumed schedule for performing preventive maintenance.

6.4.2 CREW TIME DEVOTED TO MAINTENANCE

The requirement for manual assistance in fault isolation procedures was reviewed for all LRUs in the DM, GN&C, and RFC subsystems. It was estimated that 40 percent of the faults detected by the checkout software required assistance of the crew for isolation to a single LRU. The source of this estimate is shown in Table 6-5. All of these faults would require time for removal and replacement of the faulty LRU. This time is estimated at 0.8 hour per incident. Of the faults that require manual assistance, it was estimated that 2/3 of the 40 percent requiring manual assistance or 27 percent of the total faults could be isolated by manual intervention at the central Control and Display Console. The average time for this isolation was estimated at 1.1 hours. The remaining 1/3 of the faults that

Table 6-4. Sample Computation for Expected Number of Maintenance Incidents (Failures)

$F = N \lambda T$

WHERE N = QUANTITY OF LINE ITEM USED IN THE SUBSYSTEM

λ = FAILURE RATE = $\frac{1}{MTBF}$

T = LENGTH OF FORECAST PERIOD

S-BAND VIDEO RECEIVER

N = 10

$\lambda = \frac{1}{715K} = 1.4 \times 10^{-6} \frac{\text{FAILURES}}{\text{HOUR}}$

T = CLOCK HOURS IN

3 MONTHS = x = 2.19×10^3

6 MONTHS = 2x = Y

36 MONTHS = 6Y

	(N)		(λ)		(T)		FAILURES EXPECTED
3 MONTHS	10	x	1.4×10^{-6}	x	2.19×10^3	=	.0306
6 MONTHS	.0306		x	2	=		.0611
36 MONTHS	.0611		x	6	=		.368

require manual assistance or the remaining 13 percent of the total faults would require local intervention. The total time required for isolation was estimated at 2.2 hours. The average time per incident as a result of these figures is 1.8 hours which includes a factor of 30 percent for retries.

Crew involvement in each step was estimated as indicated in Table 6-6. The resulting total manhours per incident is 3.0. A brief survey was made to verify these figures using IBM commercial equipment experience as a guide. The results are shown in Table 6-7.

Four units that are typical of a Data Management Subsystem were selected and their unscheduled and scheduled manhours per incident were estimated using commercial experience as a base. The quantity of each unit used in the Space Station Data Management Subsystem are also listed in Table 6-6. The ratio of failures among the four types of units was computed from the subsystem to MTBF data. This information was factored and averaged to provide the result of 1.8 hours per unscheduled maintenance incident and 1.7 hours per scheduled maintenance incident.

Table 6-5. Automatic Fault Isolation Efficiency

Subsystem	LRUs Considered	LRUs Requiring Manual Assistance for Fault Isolation
DM	59	32
GN&C	39	7
RFC	46	19
Total	144	58

40 percent of faults require manual assistance to isolate to the LRU level. (See Appendix B.)

Table 6-6. Crew Time per Incident

No. of Incidents	Fault Isolation Hours	Fault Isolation Men	FI Manhours	R&R Hours	R&R Men	R&R Manhours	Total Hours	Total Manhours
A	B	C	D	E	F	G	H	T
60	---	--	---	1.0	1.5	1.5	60	90
27	1.4	2	2.8	1.0	1.5	1.5	65	116
13	2.9	2	5.8	1.0	1.5	1.5	51	95
						Totals	176	301

NOTES: 100 incidents assumed
Col. D = Col. B x Col. C
Col. G = Col. E x Col. F
Col. H = (Col. B + Col. E) x Col. A
Col. T = (Col. D + Col. G) x Col. A
Quantity in columns B and E contains a factor of 30 percent for retries.

$$\text{Av. Hours/Incident} = \frac{176}{100} \cong 1.8$$

$$\text{Av. Manhours/Incident} = \frac{301}{100} \cong 3.0$$

Table 6-7. DMS Maintenance Manhours per Incident (Commercial Experience)

Unit	Un-scheduled Manhours per Incident	Scheduled Manhours per Incident	Quantity (Q)	Incident Ratio (IR)	Factored Hours	
					Unscheduled	Scheduled
Magnetic Tape	1.0	0.3	9	30	270.0	81.0
Magnetic Disc	3.0	4.0	6	30	540.0	720.0
Main Memory	1.5	1.8	16	1	24.0	28.8
Central Processing Unit	1.2	0.3	6	5	36.0	9.0
	(Q . IR) = 496				870.0	838.8
	Average Hours per Incident				1.8	1.7

When the involvement of more than one crew member is considered, the total manhour expenditure is 3.0 hours. This value is used as the basis for the Data Management Subsystem average manhours per unscheduled maintenance incident. A somewhat smaller figure of 2.7 hours per incident was used for the other subsystems because of the electromechanical equipment included in the Data Management Subsystem. These values are summarized in Table 6-8, where it can be seen that the total number of manhours involved in unscheduled maintenance for the electronic portions of the subsystems was computed to be 101 for the 180-day resupply period. An equal number of manhours was estimated for scheduled maintenance activity. Note in Table 6-8 that there are 202 manhours of maintenance activity (both scheduled and unscheduled) in the 180-day period. This amounts to an average of 1.13 hours per day or 7.9 hours per week.

It is important to note that only 13 percent of the total maintenance incidents actually involved use of test equipment; therefore, an average of 0.36 incidents per week required the use of test equipment. If fault isolation by substitution is allowed, none of the unscheduled incidents require the use of test equipment.

Table 6-8. In-Place Fault Isolation - LRU Level Replacement

Electronic Subsystem	Unscheduled (1) Incidents/ 180 Days	Manhours/ Incident	Total Manhours	Scheduled (2) Incidents/ 180 Days	Manhours/ Incident	Total Manhours	Total per 180 Days
DMS	23	3.0	69	23	3.0	69	138
GN&C	3	2.7	8	3	2.7	8	16
RFCS	2	2.7	5	2	2.7	5	10
Other	7	2.7	19	7	2.7	19	38
Total	35	---	101	35	---	101	202

(1) Isolate/Repair/Verify
(2) Preventive/Calibration/Pre-installation

$$\text{Total Mhrs/day} = \frac{202 \text{ hours}}{180 \text{ days}} = 1.13$$

$$\text{Total Mhrs/week} = 1.13 \times 7 = 7.9$$

Unscheduled Incidents per Day (35/180)	0.2
Scheduled Incidents per Day (35/180)	0.2
Total Incidents per Day	0.4
Total Incidents per Week	2.8

Incidents Requiring Test Equipment per Week
Substitution 0.0 Test Interface 0.4

6.4.3 MAINTENANCE SPARES

The next step in the LRU replacement level study was to estimate the weight of spare parts required for various resupply cycles and spares availability confidence levels. The electronic portions of the DMS, GN&C and RFC Subsystems were estimated to weigh 9160 pounds, as shown in Table 6-9. The remaining subsystems' electronics were estimated at 20 percent of the total weight of eletronic assemblies. The basic subsystem electronics weight was estimated at 11,450 pounds.

Weight of spare LRUs was computed for resupply intervals of 3, 6, and 36 months and availability confidence levels of 95 percent and 99 percent. The quantity of spare LRUs was computed on the basis of individual LRU MTBF estimates. The results are shown in Table 6-10. They indicate that a Space Station resupplied at three-month intervals but having spares on board for a six-month resupply cycle would require approximately 2500 pounds of spares for a 95 percent confidence level and 4500 pounds of electronic spares for a 99 percent confidence level. A non-resupplied mission having a duration of 36 months would carry 10,000 pounds of electronic spares for a 95 percent confidence level and 16,000 pounds of electronic spares for a 99 percent confidence level.

Table 6-9. Subsystem Electronics Basic Weight (lbs)

LRU Level Replacement		
DMS	5,700	
GN&S	1,680	
RFCS	1,780	
	9,160	80% estimate
EC/LS)		
Prop)	2,290	20%
Struct)		
Pwr)		
	11,450	

Table 6-10. Subsystem Spares Weight (lbs)

Sub-System	Resupply Cycle/Confidence Level 3 mo 95	3 mo 99	6 mo 95	6 mo 99	36 mo 95	36 mo 99
DMS	894	2, 362	1, 864	2, 938	7, 553	11, 406
GNC	48	228	83	582	761	1, 006
RFCS	24	86	34	103	200	350
Total	966	2, 676	1, 981	3, 623	8, 514	12, 760
Other	242	669	495	906	2, 128	3, 190
Total	1, 208	3, 345	2, 476	4, 529	10, 642	15, 950

Figure 6-1 compares LRU level spares requirements with the basic subsystem weight for the two confidence levels. For example, a mission having a duration of 36 months would require spares equal to the weight of basic subsystem electronics to achieve a 95 percent confidence level. To achieve a 99 percent confidence level, spares' weight would be 150 percent of basic subsystem electronics weight.

6.4.4 SUMMARY - LRU LEVEL REPLACEMENT

This portion of the study points out that subsystem reliability (MTBF) and the drift and wearout characteristics of the subsystem equipment are dominant factors in the definition of a Maintenance Capability.

The unscheduled and scheduled maintenance incidents predicted for the Space Station average less than 3 per week. The Checkout Subsystem is 60 percent effective in automatically locating faults to the level of a single LRU. With limited assistance from the crew, executing fault isolation procedures at a central Control and Display Console, 87 percent of the unscheduled incidents are corrected by removal and replacement of the LRU indicated by the Checkout Subsystem. The remaining 13 percent of the unscheduled maintenance incidents require intervention in terms of LRU substitution or monitoring of test interfaces.

The degree of automation of the scheduled maintenance incidents may be similar to that predicted for the unscheduled incidents. For example, calibration procedures are expected to be semiautomatic. A crew man may enter calibration parameters. Error data will be automatically acquired and entered into error matrices.

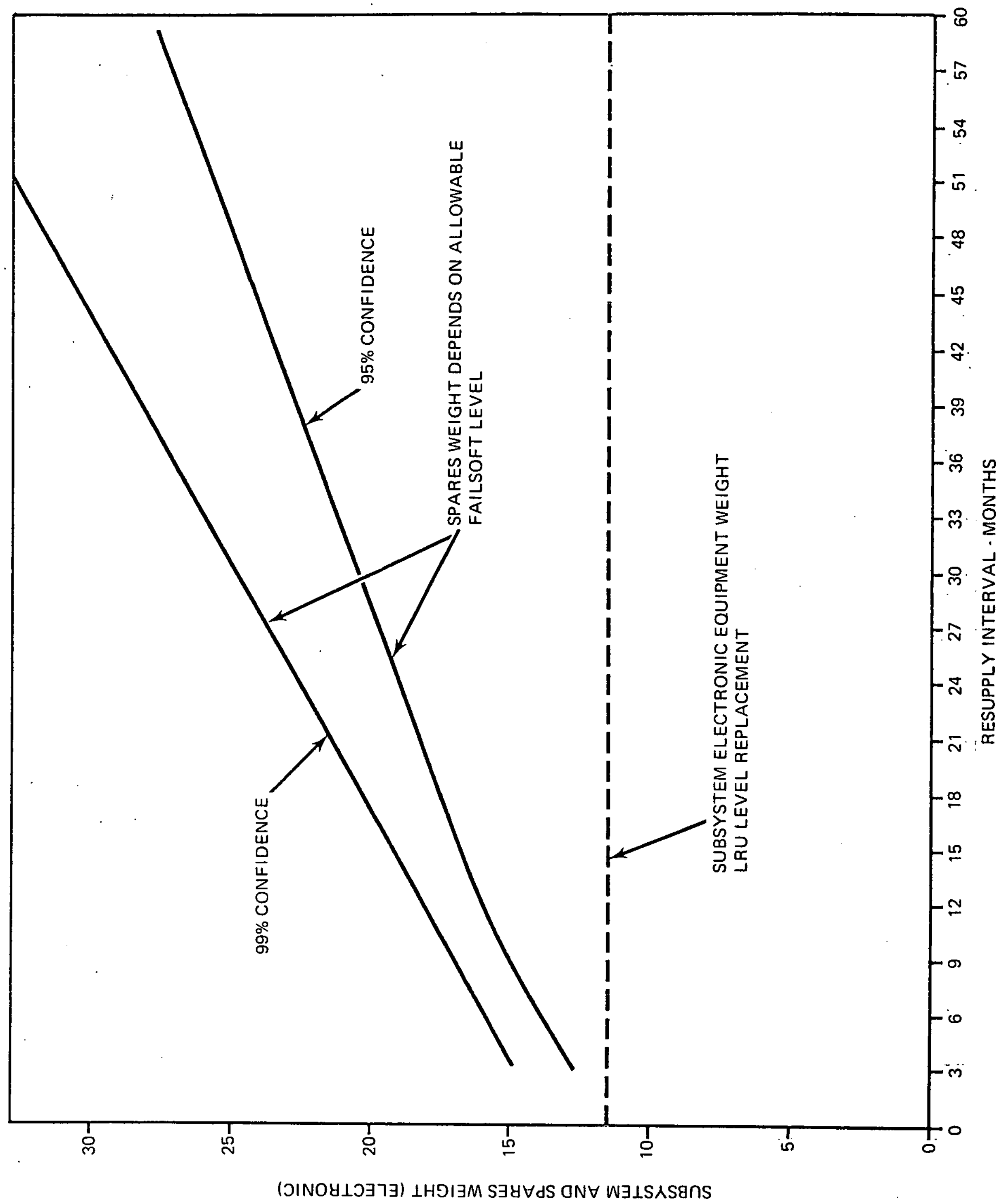

Figure 6-1. Spares Weight Requirements LRU Level Replacement

The need for pre-installation checkout of assemblies is expected to be minimal. In instances when it is necessary, the check will most likely be performed using software and will not require monitoring of test interfaces.

Scheduled maintenance incidents that result from wearout characteristics of electromechanical assemblies or from drift characteristics of designs that are at the limit of the state-of-the-art may form the greatest requirement for a maintenance capability.

Scheduled maintenance can be further minimized on Earth orbital missions by replacing assemblies such as magnetic tape and disc units and refurbishing them at a ground depot.

Results of this portion of the study are summarized in Table 6-11. Conclusions regarding LRU level replacement are as follows:

1. The expected involvement of crew members in maintenance at the LRU level does produce a significant impact on crew activity scheduling.

2. The requirements for test equipment, if isolation by substitution is allowed, can be limited to the equipment needed to adjust for wearout and drift. Both of these requirements can be minimized on Earth-Orbital missions by periodic replacement of the assemblies or by adequate spare assemblies on board.

3. The low number of maintenance incidents does not justify a central test facility.

4. A sparing philosophy that allows a high confidence level for availability of spare assemblies precludes the need for a central repair facility.

The conclusions given above, even though they strongly indicate that a centralized Maintenance Facility is not needed for Earth Orbital missions, are not meant to indicate that the need for a significant maintenance capability does not exist. The maintenance capability, consisting of items such as hand and power tools, portable test equipment, portable data entry and display unit, maintenance documentation file and viewing unit, and crew and spare assembly restraining and translation devices, will be addressed during the rest of the study.

Further, this portion of the study has not fully considered the unique requirements of long duration, non-resupplied missions. Some of these requirements are explored in the following paragraphs.

Table 6-11. Summary-LRU Level Replacement

LRU LEVEL REPLACEMENT

All maintenance in place

No repair

FACTOR	REQUIREMENT
Incidents	
Total	2.8 per week
Requiring Test Equipment	.36 per week
Crew Time	
Total	7.9 manhours per week
Using Test Equipment	1.0 hour per week
Weight	
Spares for 6 months Resupply Cycle	2500 lbs at 95% confidence 4500 lbs at 99% confidence
Tools, Test Equipment Documentation, Maintenance Aids	600 lbs (estimated)

The final decision regarding the need for a centralized facility may also be impacted by consideration of the test and repair requirements for other than electronic equipment, such as electrical, chemical and mechanical assemblies.

6.5 SRA LEVEL REPLACEMENT APPROACH

This portion of the report compares LRU and SRA levels of replacement and considers physical repair of non-pluggable SRAs.

An LRU/SRA comparison using the LRU data as the baseline is shown in Table 6-12.

The SRA approach assumes a mix of pluggable and non-pluggable assemblies. SRA design reliability would be decreased due to added connectors but might also be strengthened by increases in commonality. This comparison assumes the SRA design could be as reliable as the LRU design. The number of unscheduled maintenance incidents, therefore, would remain essentially the same.

Table 6-12. LRU/SRA Comparison

Maintenance Factors	LRU Estimates	Mix of Pluggable and Non-Pluggable SRA	SRA Estimates
Reliability		Decreased due to added connectors. Increased due to added design commonality.	
Maintenance Incidents			
Unscheduled	1.4/week	No change if reliability is not changed.	1.4/week
Scheduled	1.4/week	Slight increase due to pre-installation tests.	2.1/week
Crew Time			
Unscheduled	3.9/week	Increased due to lower level of fault isolation.	11.9/week
Scheduled	3.9/week	Slight increase due to pre-installation tests.	5.6/week
Weight			
Subsystem	11450 lbs	Increased due to connectors.	12,500 lbs (10% inc.)
Spares	4529 lbs for 180 days at 99% C.L.	Decreased by weight of LRU structure and other very high reliability assemblies.	3,170 lbs (30% dec)
Tools - Test Equipment - Maintenance Aids	600 lbs	Increased documentation. Central facility required for repair of non-pluggable assemblies. Some additional tools for removal and replacement	Up to 1,200 lbs increase

The number of scheduled incidents for calibration and preventive maintenance would also remain essentially the same. There might, however, be some slight increase in the need to perform pre-installation test due to the greater number of pluggable assemblies.

Crew time requirements would increase as the levels of replacement increase, assuming the automatic fault isolation capability remains at the LRU or multiple LRU level.

Crew time for scheduled maintenance should remain the same, because preventive maintenance and calibration procedures would remain essentially the same.

The crew time for unscheduled maintenance would definitely increase because of the added time to isolate to the SRA level. It has been estimated that unscheduled maintenance crew time would increase by a factor of 3. The overall increase in utilization in crew time would be from 8.4 to 17.5 hours per week.

As the level of pluggability or replaceability is increased, it is estimated that there would be as much as a 10 percent increase in the basic subsystem weight. This will amount to a penalty of 1145 pounds. However, because of the increase in level of replaceability, an overall decrease in spares weight of about 30 percent is predicted. For example, the 4529 pounds predicted for achieving 99 percent confidence level for a 180-day resupply period would be reduced to approximately 3000 pounds.

The lower level of replacement and the need to replace non-pluggable assemblies also will increase the quantity of tools, test equipment, and maintenance aids. An increase of 1200 pounds beyond that needed for the LRU level replacement is estimated. This figure does not include the capability for fault isolation and operational verification in a central facility. It does include the facilities to repair to the lowest replaceable level and to test the quality of physical repair.

It should be noted that if it were possible to provide software to isolate to the SRA level and if all SRAs were pluggable and substitution were permitted, then no test equipment would be required. This is believed to be a prohibitively idealistic approach.

The overall impact on weight due to SRA level of replacement is shown in Figure 6-2. The basic subsystem and Maintenance Facility weight to support SRA level of replacement is approximately 2300 pounds, or 20 percent more than the weight of subsystems and Maintenance Facility required to support LRU level

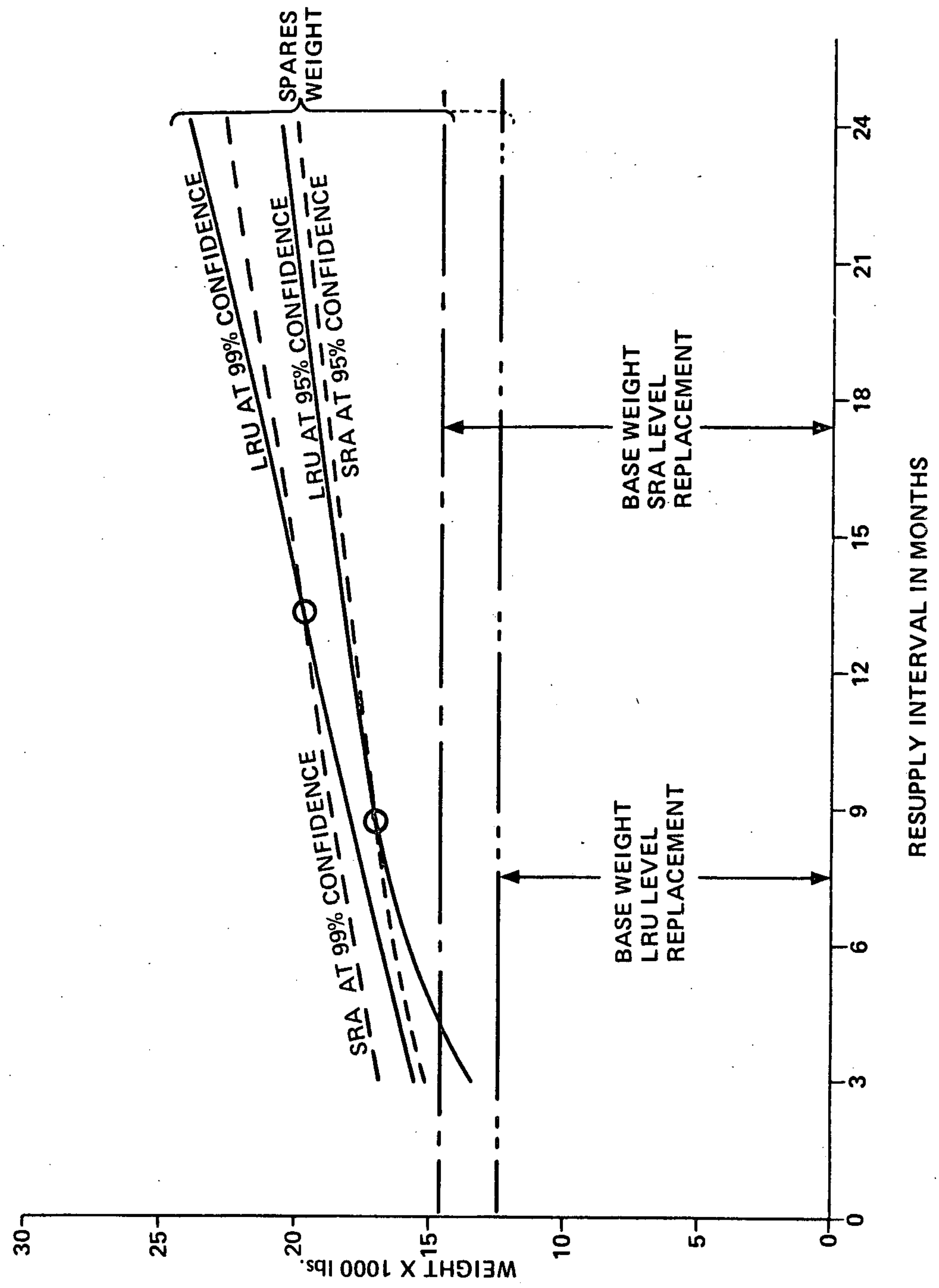

Figure 6-2. LRU/SRA System Weight Comparisons

replacement. There is a cross over in total weight in the range of an 8-to-15-month resupply interval, depending upon the confidence level required for the mission.

6.6 CONCLUSIONS

The most significant conclusions at this point in the study are:

- LRU level replacement and in-place maintenance are recommended for resupplied missions.
- A capability for SRA level repair should be developed.
- A Maintenance Facility should be included in the Space Station to develop techniques and acquire experience in in-space maintenance/ in preparation for long-duration, non-resupplied missions.

Long duration, non-resupplied missions will need the capability for SRA level replacements and repair. The success of this level of replacement depends upon achieving a high degree of pluggability, in-place fault isolation, in-place preventive maintenance, and design commonality. If these items can be achieved, then SRA level replacement is feasible, especially if it is supported by low level fault isolation software and the ability to substitute assemblies as opposed to monitoring test interfaces.

The long duration mission should have a central facility for repair. However, its primary purpose may not be for repair of an anticipated fault, since pluggable spares will be available to account for most of these faults. The main function of the facility is to provide for the recovery from design problems that are not discerned before the spacecraft is launched or for accidents that happen during the mission which result in using all available spare assemblies. The central facility, therefore, is essential for working around problems that are unforseen in addition to supporting the repair actions that can be anticipated.

Section 7

TOOLS AND TEST EQUIPMENT

Presently available definitions of Space Station subsystem and equipment designs are not adequate for precise specification of tools or test equipment. It is feasible, however, to predict qualitatively what the requirements will be.

It has been previously concluded that, for resupplied missions, the preferred electronic maintenance approach is one in which fault isolation is to the LRU, and repair is effected by removal and replacement of LRUs. The maintenance items needed to support this activity are indicated qualitatively in Table 7-1. If fault isolation and replacement extend to the SRA level, then additional maintenance items are needed, also as shown in Table 7-1.

A considerable amount of in-place maintenance activity is expected in the resupplied Space Station. The Portable Astronaut's Test Kit described briefly in Subsection 7.1 is an excellent start toward providing maintenance items to support that activity. Additional central maintenance items will be needed, as listed in Subsection 7.2.

7.1 PORTABLE ASTRONAUT'S TEST KIT (PATK)

Initial design and fabrication of a kit to contain the tools and test equipment that an astronaut would need for inplace maintenance on a space vehicle were done in 1969-1970 by Martin-Marietta Corporation under a contract to NASA-MSFC. The final report on this contract is referenced (item 19) in Subsection 3.6. This kit was designed to meet the requirements of representative inplace maintenance tasks which included mechanical and electromechanical maintenance tasks rather than electronic maintenance tasks. The following representative tasks were demonstrated in simulated space conditions using the contents of the kit:

- Removal and replacement of a typical spacecraft mechanical system fluid pump.
- Inplace fault confirmation, and subsequent removal and replacement of a battery charger and regulator module.
- Inplace fault diagnosis of a command-signal type, manually operated, rotary switch.

Table 7-1. Maintenance Item Requirements

Types of Maintenance Items	Required for LRU	Required for SRA
Meters	X	X
Oscilloscopes		X
Maintenance Aids	Nominal	More detailed
Procedures Viewer	X	X
R&R Tools	X	X
Assembly Tools		X
Positioners	X	X
Restraints	X	X
Multipurpose Test Equipment		X
Power Tools		X
Data Entry and Display	X	X
Intercom	X	X
Diagnostic Routines	X	More detailed
Stimulus Generators		X
Analyzers		X
Loads		X
Skill	Nominal	Greater

- Removal and replacement of a typical spacecraft mechanical system pressure regulator valve.

- Removal and replacement of a typical spacecraft system, fluid-line installed, pressure transducer.

The following items were selected to be included in the basic kit or special purpose sub kits:

1. Installed or Incorporated in Kit

    a. Electrical Multimeter (one)

    b. Portable lights (two hand-held, extendible with mounting provisions

c. Task procedures readout device (one, lighted panel)

d. Test probes (compatible with 1.a, above)

e. Kit mounting boom (one, foldaway type)

f. Battery power supply (one, integral, mockup)

g. Small spares stowage compartment (one or more)

h. Large spares mounting panel (one or more)

i. Astronaut carrying and translation handle (one, fixed)

j. Work-shelf-type panel with parts restraint devices (one)

k. Tether connection fixtures (two or more)

l. Astronaut and equipment tethers (two or more)

2. Carried or Stored in Kit

a. Screwdrivers (set; includes panel fastener tool)

b. Pliers (one)

c. Crescent wrench (one)

d. Diagonal wire cutters (one)

e. Metal shears (one)

f. Tape dispensing reels (two)

g. Safety wire dispenser (one)

h. General purpose tie cord dispenser (one)

i. Leak seal material dispenser (one)

j. Fluid containment device (one)

k. Mechanical leak seal plugs (set)

l. General purpose rags (one or more)

m. Velcro tape fastener patches (set)

n. Electrical test leads with clips (two)

3. Carried or Stored in Sub-Kits

a. Mechanical

(1) Deep-well socket set (3/8 inch drive)

(2) Ratchet for socket set (one)

(3) Open-end wrench set

(4) Vise grips wrench (one)

(5) Allen wrench set

(6) Thread cleaning/deburring tool

(7) Parts retriever tool

(8) Soft face hammer*

(9) Drift punch*

(10) Torque wrench*

(11) Leak detector*

(12) Vacuum and pressure sensing and measuring device*

(13) Portable N_2 storage and spray container*

(14) Window glass cleaner*

(15) Decontamination kit*

(16) Ablative material kit*

*These items are reserved for sub-kits that could be formulated, but are not furnished as elements of the mockup kit.

(17) Space suit repair kit*

(18) Electron beam welder*

(19) Portable vacuum cleaner*

(20) Small portable power tool kit*

(21) Elapsed time indicator*

b. Electrical

(1) Pin alignment tool (one)

(2) Electrical Connector tool (one)

(3) Wire stripper and crimping tool (one)

(4) Terminal lugs (set)

In developing the contents of each of the kits, attention was given to functional grouping of elements and desired presentation to an astronaut in a typical spacecraft. Design criteria for packaging development included the following:

1. One astronaut will manually transport the kit from location to location.

2. The kit shall easily pass through a 24-inch diameter opening.

3. The kit shall be suitable for use by an astronaut in the following environmental modes:

   a. IVA, astronaut in "shirt-sleeve" uniform

   b. IVA, astronaut in unpressurized space suit

   c. IVA, astronaut in pressurized space suit

   d. EVA, astronaut in pressurized space suit

4. Specialty tools may be considered being available in modularized, sub-kits that can be attached to the basic kit.

*These items are reserved for sub-kits that could be formulated, but were not furnished as elements of the mockup kit.

This kit, or sub-kits, would be stored in the maintenance facility. It contains the majority of the hand tools that would be required for activities in the maintenance facility as well as for remove-and-replace requirements in place.

7.2 ADDITIONAL CENTRAL MAINTENANCE ITEMS

The following maintenance items are required in the Central Facility in addition to those included in the Portable Kit.

1. Work bench
2. Chair with foot holds and seat belt
3. Small parts retaining shelf (magnetic or laminar flow pad)
4. Maintenance debris collection device
5. Gauges for measuring:
    a. Temperature
    b. Pressure
    c. Vacuum
6. Micrometers - 0 - 1 inch, 1-3 inch
7. EMI meter
8. Special coveralls
9. Electrical insulating materials
10. Rubber gloves
11. Emergency lighting
12. Oscilloscope
13. Oscilloscope probes
14. Connector pin insert-extract tools
15. Storage for Portable Kit and sub kits

16. Soldering kit

17. Welding kit (for electronic component interconnection)

18. Multiple-use power supply

19. General-purpose stimulus generator

20. Portable display and control unit

21. Maintenance Data storage and retrieval unit

Section 8

MAINTENANCE CAPABILITY DEVELOPMENT

The study results strongly indicate that, although a centralized electronic LRU repair capability is not required in the resupplied Space Station, the Space Station mission itself provides an excellent opportunity for development of onboard repair capability in support of later long-duration non-resupplied missions. Space maintenance development in the Space Station should be the major contributor to a total program which, building on work done prior to that time, will culminate in the complete capability desired. The basic concept is one of: (a) ground-based development of equipment, techniques, and procedures, including design of experiment/test routine to be used in the Space Station; (b) transportation of a complete experiment package to the Space Station; (c) performance of the experiments, recording pertinent data and evaluation; and (d) return of experiment equipment and data to Earth.

Important work has been done in development of human factors criteria for in-space zero-g maintenance, zero-g tool (e.g. reactionless powered rotary drivers) concepts, and the Portable Astronaut's Test Kit previously mentioned (Section 7). In order to complete the transition to the Space Station maintenance development program summarized above, several supporting research and technology tasks should be performed.

Present Skylab Program plans call for performance of several on-orbit activities which will serve as precursors to Space Station maintenance experiments. The most notable are the following. [1]

- M507, Gravity Substitute Workbench, an experiment to assess the merits of using aerodynamic and electrostatic forces as gravity substitutes.
- M507, EVA/IVA Workside Simulation, intended to evaluate the capabilities of crewmen to perform selected manual operations using various conditions of restraint.
- M512, Materials Processing in Space, to demonstrate and evaluate molten metal behavior in a space environment. Although directed toward manufacturing, this experiment should illuminate some of the problems involved in soldering under zero-g conditions.

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[1] "Mission Requirements, Skylab Missions SL-1/SL-2, SL-3 and SL-4," NASA Document 1-MRD-001C, August 1970 (DRAFT).

8.1 ADDITIONAL SRT RECOMMENDATIONS

The study has identified several maintenance aids that would be common to both Earth orbital and non-resupplied missions. Specific commonalities are:

1. Portable test module to supplement software fault isolation and to assist mechanical adjustments and calibration.

2. Hand tools required for removal and replacement of electronic assemblies.

3. Devices for transporting and positioning spare assemblies. These devices include translation equipment such as pulley systems and conveyors, foot and hand holds, and special chairs and grips that allow the astronaut to provide reactive forces necessary to maintain his position relative to the equipment.

A long-duration non-resupplied mission will require a Central Repair and Test bench for maintenance of LRUs.

The following tasks are proposed to provide further definition of maintenance equipment design requirements:

1. Design and construct a Repair and Test Bench, including small-parts retaining shelf and debris collection devices.

2. Define requirements for, design and construct a portable test assembly, based on knowledge gained from the PATK but concentrating on electronic testing.

3. Design of accessability, to include intra-vehicular movement of equipment and accessibility to test points, assemblies, and parts for maintenance.

4. Select or develop a computer program to determine spares requirements based upon all relevant parameters: reliability, resupply internal, cost, and limitation on spares storage and one-trip resupply capability. The model and program should include a mix of LRUs and SRAs.

5. Design a computer-controlled spares inventory and retrieval system capable of managing all Space Station spares, minimizing retrieval time and ordering replacements for Shuttle delivery.

6. Modify designs of subsystems and equipment (LRUs) and DMS software to achieve maximum practicable efficiency of automatic fault isolation to single LRUs. This effort is appropriate for Phase C of the Space Station program.

7. Perform a refined trade analysis between levels of onboard maintenance (LRU versus SRA) based on models which include comprehensive life cycle cost as well as more accurate assessments of resources (crew time, skill, weight, etc.) needed to support each concept. The models should be sufficiently flexible that changes in input data (especially equipment reliability) can be readily accommodated.

Other tasks could be cited but are considered less important than those listed above. The first three are of sufficient importance to warrant elaboration in the following subsections.

8.2 REPAIR AND TEST BENCH

Figure 8-1 is a conceptual drawing of a Repair and Test Bench. The bench includes two basic modules. The right-hand module is associated with physical repair of assemblies. The left-hand module provides for electronic testing of assemblies.

The right-hand module contains the hand and power tools required to perform soldering, welding (terminal), crimping, splicing, drilling, and cutting. The left-hand module contains power supplies and signal and function generators that provide the capability for limited simulation of the operational interfaces. A panel is provided for connecting the assembly under test and a patchboard is used to apply voltages and signals. An oscilloscope and multimeter are provided for test point monitoring. A documentation viewer is also provided for display of maintenance drawings and procedures. The multimeter, oscilloscope, and documentation viewer are similar in capability to the units described in Task 1.

Maintenance of electronic assemblies during a mission requires tools and test equipment compatible with the lowest level of fault isolation. Adequate tools, test equipment, training, and documentation would allow replacement levels equal to those that could be economically achieved in a ground facility. The objective of this task is the definition of a space experiment that would determine the lowest feasible level of in-flight maintenance.

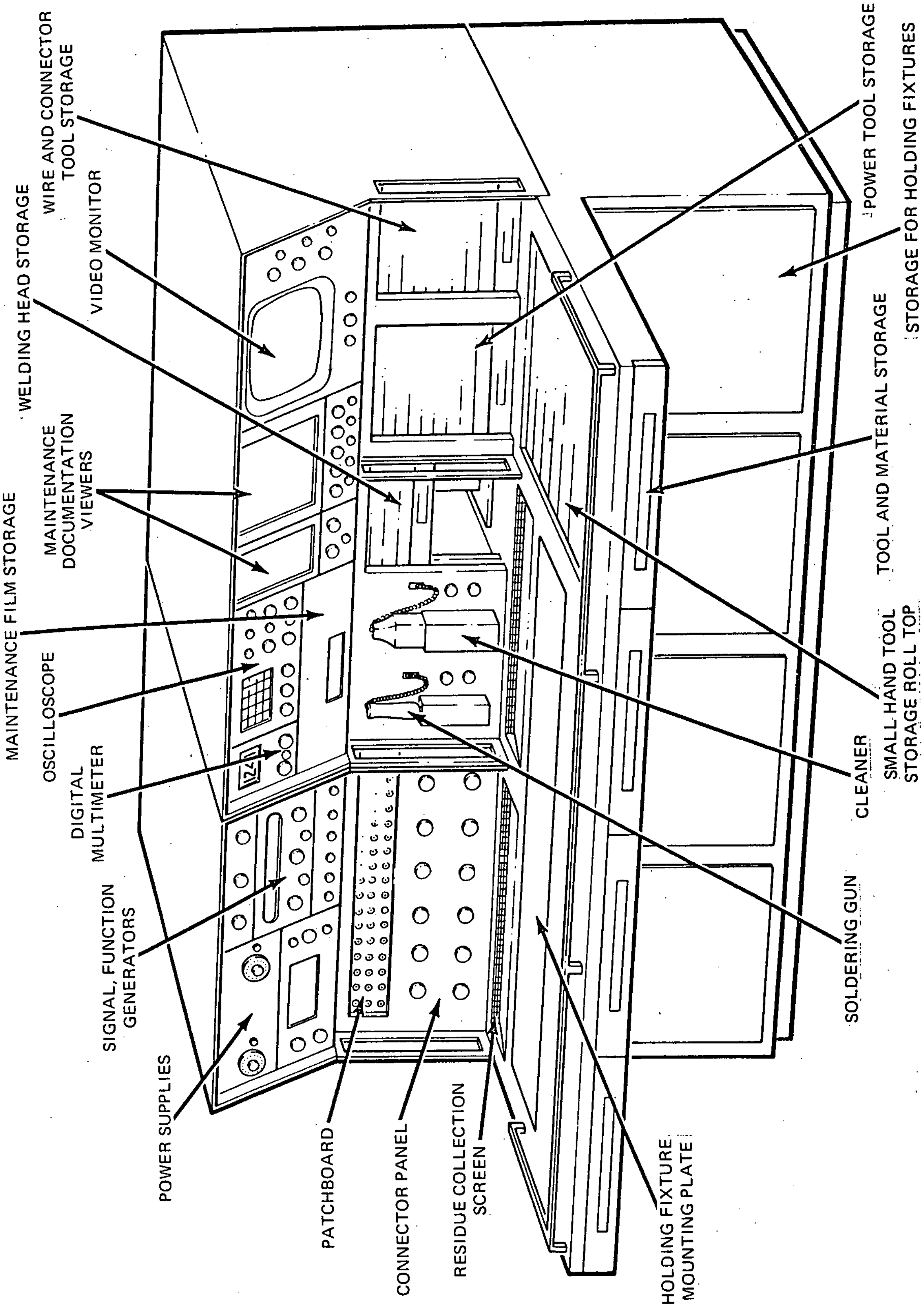

Figure 8-1. Repair and Test Bench

An in-flight maintenance facility must accommodate changes in two major parameters or conditions that exist in a ground facility. It must accommodate and it must not contaminate the environment. Accommodating these changes requires several important considerations.

1. Control of position of tools, materials, and residue.

2. Provision of a zero reaction system that will allow the astronaut to utilize tools and make control adjustments while maintaining his physical orientation with the work.

It is assumed that other problems such as adequate training, documentation, and test equipment capability can be resolved.

Features of the bench are the following:

1. All storage covers are slide or roll.

2. Cords on commonly used power tools will be fed from a reel.

3. All powered tools are controlled by switches in handles.

4. Various assembly holding fixtures are mounted to bench top and accommodate the electronic chassis.

5. A residue and small parts trap is provided in the bench top.

6. Powered and large hand tools are mounted on rotating tables in storage bins. Magnetic and mechanical latches will be considered.

7. All tools other than squeeze-operated tools may be operated with one hand. When it is necessary to hold the work and a tool, either two astronauts will be required or a specially constructed chair must provide stability.

The chair or other astronaut restraint used during the maintenance procedure should be designed so that applying tools to the equipment will not cause the astronaut to change position. A significant mechanical design and human factor problem is presented by this requirement. Underwater flotation test may be employed whenever feasible to test design approaches.

Use of devices such as a welding head requires that both the head and the assembly be attached to a holding fixture to be repaired. Welding would be performed after adjustment of the head and the work. The astronaut would not be in contact with the equipment while the weld was being made.

Other common bench activities include wire stripping and cutting, terminal crimping, and terminal insertion. Tools that are operated by squeezing are now available for these operations and, therefore, should be the most adaptable to the space maintenance activity.

This SRT task would include the following activities:

1. Design and fabrication of bench and chair mock-ups for underwater tests.

   The mock-up will be used to optimize dimensions of the bench, storage bin design, and location of controls and tools, and to access limitations.

2. Development of general specification for power supplies and signal and function generators.

3. Development of general specification for multimeter, oscilloscope, and special attachments, with emphasis on human factors requirements.

4. Design of residue collection system.

   One important aspect of in-flight maintenance is the trapping of small parts, tools, wire clippings, and other maintenance residue. The feasibility of using a low pressure air draft across the bench surface and energy absorbing screens to accomplish trapping of these items will be explored. This approach may require that the immediate volume around the test bench be shut off by an air tight wall from other portions of the spacecraft. Thus, the maintenance bench would operate in a closed system that could not affect the environment or the position of items in other parts of the spacecraft.

5. Selection or design and fabrication of sample holding fixtures.

6. Development of specification and design plan for an experimental Repair and Test Bench to be flown as an experiment.

8.3 PORTABLE TEST ASSEMBLY

Functions of the Portable Test Assembly are:

1. To perform fault isolation beyond the automatic fault isolation capability provided by the checkout software.

2. To assist calibration of analog assemblies.

3. To make analog measurements in support of mechanical adjustment procedures.

The Portable Test Assembly (Figure 8-2) described in this task assumes that stimulus generators will be incorporated in the operational system or will be available as separate test modules and will be temporarily mounted to the Portable Test Assembly. This task also assumes that communication with the processor will be accomplished by voice communication to an astronaut at the Central Control Console or by use of a Local Monitor and Display Unit (LMDU) as described in the Phase B Space Station Studies. It includes a keyboard and a CRT for entry and display of data. The unit is pluggable to the data bus at many points within the Space Station. It may be separately mounted on an extendable arm and maneuvered in close proximity to the Portable Test Assembly.

The Portable Test Assembly must have the capability to monitor both digital and analog signals. Special interfaces would be required to monitor RF signals. The basic test assembly, as shown in Figure 8-2, consists of:

1. Oscilloscope with the required probes and signal matching devices.

2. Digital multimeter.

3. Maintenance documentation viewer with provision for separate viewing of maintenance index and maintenance drawings and procedures.

Figure 8-2 also indicates access for storing and changing maintenance documentation microfilms. A drawer is provided for storing hand tools, special oscilloscope and meter attachments, and test leads. Provision is included in the drawer for capturing small parts or assemblies that may be involved in the maintenance procedure. Supplementary maintenance apparatus such as stimuli generators or special measuring devices would be fastened under the Portable Test Assembly.

Power and cooling accommodations for the test assembly would be provided through the extendable mounting arm. Details of the arm are not included in Figure 8-2, but several designs have been shown in other Space Station studies. The extension arm is fastened to the wall of the Station adjacent to power and cooling outlets. This SRT task would include the following activities:

1. Determination of allowable dimensions and weight of the Portable Test Assembly. These parameters would be defined for both Earth and space handling and positioning conditions and will consider the isle space anticipated for a 16 foot diameter equipment module. It is desirable that the assembly be mountable in and operate with the Repair and Test Bench.

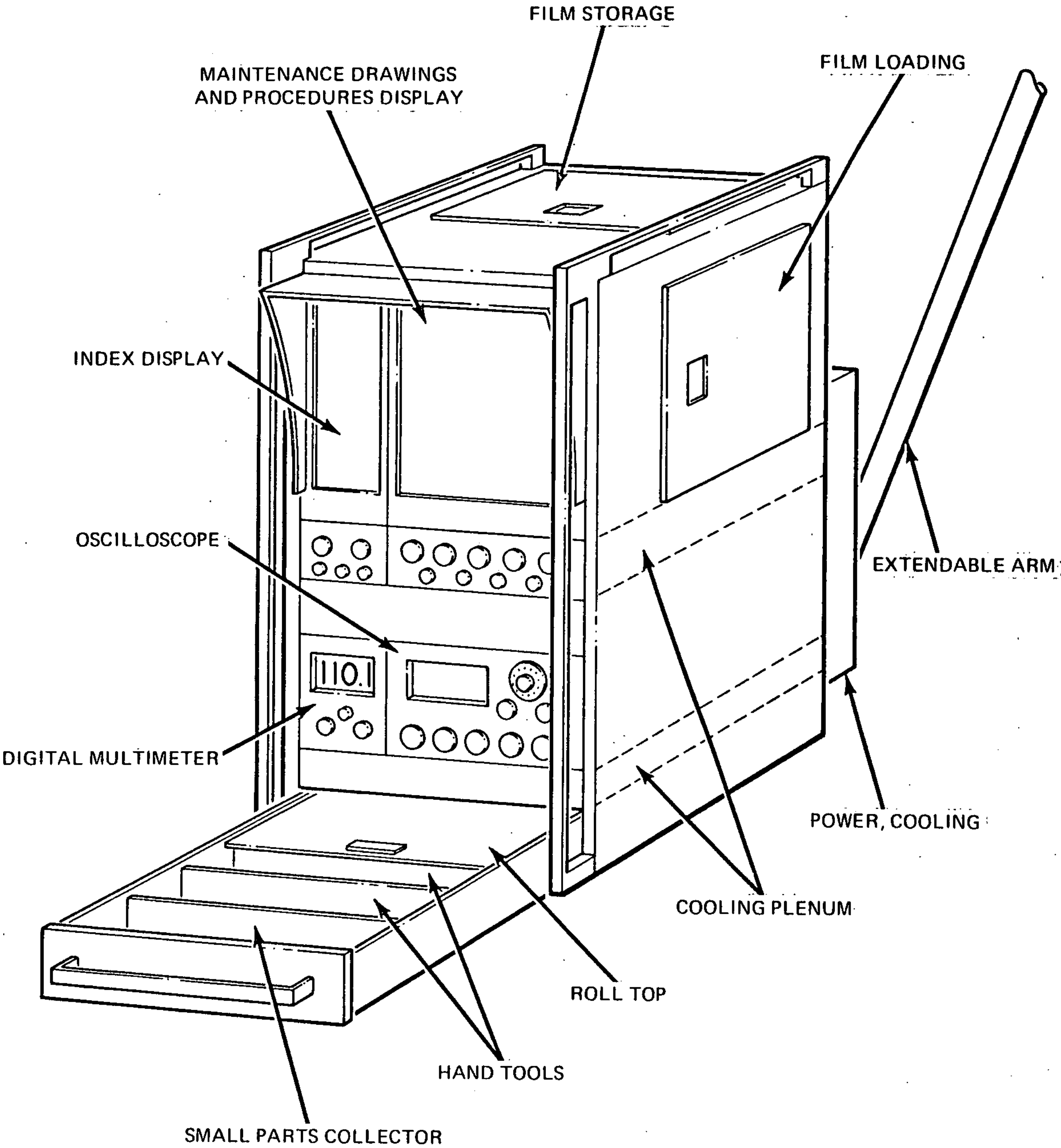

Figure 8-2. Portable Test Assembly

2. Definition of required characteristics of oscilloscope, multimeter, and special attachments that would allow widest range of usage of these instruments.

3. Definition of test assembly power and cooling requirements.

4. Organization of maintenance data, selection of storage media, and definition of retrieval and display equipment.

   Figure 8-2 indicates the capability to separately view a maintenance index and the maintenance documentation. This approach may provide the most efficient retrieval procedure. A design by Republic Aviation Division of Fairchild Hiller Corporation, called "Micro-Vue," is an example of the concept.

5. Study of the physical interface between the astronaut and the test assembly. This study will define the required ambient light level, clearances between the test and operational equipment, and means for effectively achieving zero reaction operation of detented and non-detented controls and insertion and removal of test leads. This task must also define the means for trapping small parts and tools during the maintenance procedures.

   A mockup of the test assembly will be constructed. It should be suitable for test in an underwater laboratory.

8.4 DESIGN FOR ACCESSIBILITY

This task covers three aspects of design for maintenance accessibility.

1. Transportation of spare assemblies within the spacecraft and ease of removal and replacement of electronic assemblies.

2. Accessibility to operational equipment test points for in-place testing.

3. Accessibility to test points, subassemblies, and piece parts, for bench testing and repair of electronic assemblies.

Major activities and consideration related to each task are summarized below.

The problem of transporting equipment between the maintenance and storage areas and the operational areas will require the development of translation devices. These devices may be extensions to the development of conveyor systems used in the Apollo missions and must accommodate assemblies of various dimensions, densities, and fragility. The translation harness design must consider attachment, positioning, and detachment of a wide variety of assemblies. Underwater tests will be performed to determine passage and hatch clearances, turning radii, attachment, and release of assemblies by the astronaut and time involved in performing the translation operation.

Fittings will be designed for passages, isles, and equipment racks to accommodate astronaut and equipment restraints, harnesses, and grips. These devices will be designed to be compatible with the translation equipment and removal and replacement tools.

Other studies have detailed the design of zero reaction hand and power tools and fasteners. This task will define unique requirements not covered in previous studies.

Access to test points and subassemblies can result in high penalties in terms of weight and volume. Line replaceable units defined for the Engineering Study of Onboard Checkout Techniques will be reviewed to identify units that would:

- Require test points for fault isolation, calibration, or mechanical adjustment.

- Benefit from the ability to replace subassemblies and, possibly, piece-parts.

  For example an overall reduction in weight of spare assemblies might result from the ability to replace a low MTBF item in an LRU.

The sample requirements for test points, and subassembly and piece-part replacement will be used to define accessibility criteria and test and repair tool, test lead, and special holding fixture requirements.

Packaging of electronic digital and analog circuits can have a significant effect on level of replacement. The partitioning of circuits into packages may be accomplished with different end objectives. Objectives may include:

1. Highest reliability

2. Fewest total assemblies

3. Greatest common usage of assemblies

4. Least fault isolation software

These objectives oppose each other to some extent and all cannot be applied fully to one design problem. This task proposes to explore further the benefits and penalties of partitioning selected Electronic Subsystem's elements and to optimize items 3 and 4 without compromising reliability. The results of this task will be used in the definition of test points, and characteristics of test instruments, power supplies, and signal generation equipment proposed for the Portable and Bench Test Assemblies.

Another task is the determination of the feasibility of a standard interface. The standard interface would be a common interface design applied to all major interfaces within the Data Management Subsystem. One purpose of a standard interface would be to minimize the complexity of test equipment required to provide an operational environment for dynamically testing a Line Replaceable Unit. For example, if a peripheral device such as a disk file were to be tested in the maintenance facility, the standard interface design would allow direct connection of the disk channel to a data bus terminal. Standard software could be used to exercise the disk. If a standard interface is not provided, it would be necessary to include a data bus controller, CPU, and core memory in the Maintenance Facility in order to test a disk. The result would be more equipment to maintain and additional penalties of power, weight, and volume. One alternative would be to use spare operational assemblies as test equipment. This approach could result in carrying an additional set of operational spares in order to have testing capability when the normal complement of operational spares was exhausted.

Appendix A

MAINTENANCE REQUIREMENTS ANALYSIS DATA SHEETS

The Maintenance Requirements Analysis matrix provides a synoptic view of the maintenance requirements of each major electronic subsystem. The analysis, when complete*, will consider all elements of the Data Management and Communications Subsystems and major electronic control elements of the Guidance, Navigation, and Control and DMS and RF Communication Subsystems. The information on the matrix may be used to examine the following factors that affect the overall availability of subsystem equipment to conduct stationkeeping and experiment operations.

- Consistency of operational recovery methods based on software reconfiguration and critical down time limitations.
- Ability to maintain adequate operational capabilities while failed equipment is being removed, replaced, and verified.
- Overall summary of periodic preventive maintenance requirements for calibration and adjustment of electronic and electromechanical equipment.
- Similarity of maintenance tools, test equipment, training, and facilities requirements among and within subsystems.
- Availability of astronaut time to perform preventive and corrective maintenance.

The following are descriptions of the headings of each column in the Maintenance Requirements Analysis matrix.

<u>Column 1 - Group</u>

A group is a major element of a subsystem, usually containing several Line Replaceable Units.

*Completion of the MRA on all subsystems is beyond the scope of the present contract.

Column 2 - LRU/SRA

A Line Replaceable Unit (LRU) is defined as any assembly which will be replaced in order to restore a subsystem or group of equipment to functional (operational) status. Fault isolation to an LRU is a Space Station goal. Automatic fault isolation to this level may not be economically feasible in 100 percent of the situations encountered. In those situations where automatic fault isolation does not reach the LRU level, manual intervention will be required to get from the line isolatable unit (LIU) level down to the LRU level.

The automatic checkout approach also connotes that all subsystem elements will be designed so that operational recovery from the fault can be achieved automatically through system reconfiguration, even though in some instances degraded operations will result. Each horizontal division on the analysis matrix identifies an LRU. The charts at the end of this appendix list all LRUs associated with each equipment group. The top line in each horizontal section of the matrix is the name of the LRU. The indented titles are estimates of functional blocks that could represent shop replaceable assemblies SRAs. The following factors were considered in defining the LRUs:

- The maintenance concepts developed and defined in subtask 1-3.
- The component level failure rates delineated in the criticality analysis of subtask 1-2.
- The amount of crew time and skill required for fault isolation and repair.
- Resultant DMS hardware and software complexity.
- Subsystem weight, volume, location, and interchangeability characteristics.

The SRA is defined as that element of an LRU that will be replaced at the Maintenance Facility by a remove-and-replace action to restore LRU serviceability. Test equipment will be required to isolate the fault from the LRU level down to the SRA level. In some instances it may be desirable to continue the fault isolation in place before LRU removal. In this instance the SRA to be replaced would already be identified when the LRU comes into the Maintenance Facility.

Column 3 - Quantity in System

The numbers in Column 3 that refer to the LRU indicate the quantity in the application being considered, the quantity of operating or stand-by redundant spares, the quantity of laid-in spares, and the total usage of the LRU on board the Space Station.

The number should be a coarse indication of system reconfigurability and multiple usage of replaceable assemblies. In instances where a single LRU is indicated, a potential system availability problem exists, especially if that LRU cannot be configured out of the system without serious degradation to the operation of the spacecraft or experiments. A single LRU indicates the loss of a function during the time period for removal, replacement, and verification.

The quantities in Column 3 that relate to the SRAs indicate the replications of logical functions within the LRU. In instances where several books comprise one LRU, it is likely that these will be mechanically interlocked and all removed and replaced simultaneously.

Column 4 - Number of Books

This column presents a preliminary estimate of the number of standard books required to package the LRU/SRA functions. Functions that require less than one book should be grouped so that the software reconfiguration to overcome a fault situation is minimized.

Column 5 - MTBF

A mean-time-between-failure figure was estimated for each LRU. The LRU MTBF is essential because this is the replacement level for recovery of full operational capability. The MTBF figures will be used to determine the expected number of unscheduled maintenance actions during a resupply period. The figures are particularly beneficial because they form the justification for maintenance techniques and the capability of the Maintenance Facility. These figures, along with the mean-time-to-repair (MTTR) and Calibration estimates, provide a good measure of the expected involvement of astronauts in maintenance tasks. The MTTR figures also determine, to a large extent, the expected availability of the electronic subsystems.

Column 6 - Critical Down Time Limit

This column is included to help indicate the need for the wired-in spares or redundant equipment. It is also a basis for determining the speed and methods required for software reconfiguration. If a storage element, for example, has a critical down time limit of only a few minutes, it would be essential to store the data in two portions of the memory system so that the software could immediately recover critical data, reassign the program to an alternate storage element and proceed.

Loss of some portions of the equipment, such as the dedicated memory, might result in a degraded operation that was safe for only a short period of time. It also might result in a lessening of the capability of the MDS to continue the periodic self-check procedures. The physical recovery to operational status might be best achieved by pulling the entire memory element along with the decoder and interface logic and replacing them with spare units. This may be necessary even though a "wired-in" spare or redundant equipment is immediately switched into the system. The critical down time limit number normally indicates recovery time for operational software reconfiguration or for bringing a redundant or wired spare on line.

Column 7 - Software Reconfigurable

One requirement in the definition of an LRU is that it must be reconfigurable under control of the DMS; otherwise, the system could not gracefully recover from a fault at the LRU level. However, there are several modes of software reconfigurations. These include: switching in of a redundant path, bringing a wired spare on-line, or substituting another on-line unit to perform the function of the failed LRU.

Three types of reconfiguration have been identified: fail safe, fail soft, and system reconfiguration. Fail safe reconfiguration can be achieved by having an on-line redundant unit that may be immediately switched in and that will allow the normal software operation to continue with minimal interruption. The fail soft reconfiguration may take several forms. One form is a second-level fail safe approach which would allow time for powering up a wired-in spare. Once the wired-in spare is brought on-line, the system can continue operation without any degradation. An example of another form of fail soft reconfiguration is the substitution of unused or less critical portions of the main or auxiliary memory for a failed portion. This approach presupposes that critical data is periodically stored in more than one section of the main or auxiliary memory. The amount of redundant data stored depends upon the time allowable for recovery. For example, certain critical guidance and navigation information or critical experiment information may be stored periodically in two sections of memory. Reconfiguration is achieved by falling back to the last time interval at which adequate information is available in the alternate memory.

Column 8 - Fault Isolation Scheme (On-Line)

Column 9 - Manual Fault Isolation Requirements (On-Line)

This column summarizes the astronaut activity that would be required to supplement the automatic DMS software operations. The information in this column is limited to manual intervention to supplement fault isolation to the LRU level while the equipment is on-line. The goal of the DMS, of course, is to have no manual fault isolation requirements; however, some instances may occur where the astronaut must enter supplementary data or use display data to make judgments as to the DMS software programs that should be exercised to isolate a fault. The information in this column will also assist in determining whether adequate reconfiguration capability is being designed into the system and whether the astronaut intervention is consistent with the critical down time limits.

Column 10 - Operational Recovery Scheme

Information in this column indicates the means for maintaining subsystem operation while the faulty unit is still in place. Certain types of failures may preclude continued operation of the subsystem with the faulty unit in place. The objective would be to design LRU interface circuits such that no fault within an LRU can affect the operation of any other LRU. There are certain limitations to this objective, such as shorts between connector pins and limitations involving components that immediately interface the power bus or components of other LRUs.

One requirement for the design of LRUs should be that each LRU will have its own power control. The Power Distribution System must be designed so that any LRU may be switched on or off without affecting the operation of any other LRU. LRU interface circuits should also be designed so that a redundant or wired-in LRU may be removed without affecting system operation.

Column 11 - Mean-Time-to-Repair (Hours)

The mean-time-to-repair (MTTR) figures are estimates of the time to restore the system to operational status after the DMS has isolated the fault to the Line Isolatable level. The MTTR figure will be estimated on the basis of repair times for similar equipment in ground installations and then converted to the zero-g space environment by application of the "derating" factors found in Table A-1. (This table was extracted from Section 10 of reference 11 where it was designed as Table 10-8). Time required to fetch a spare LRU from storage will also be included in the MTTR.

Table A-1. Maintenance Derating or "K" Factors for Maintainability Predictions Derived from Zero-G Demonstrations

A. From One-g to Zero-g in Shirtsleeves and Foot Restraints

For EVA Black Boxes: $K = \frac{\text{138 Seconds (Zero-g in S.S.)}}{\text{133 Seconds (One-g in S.S.)}} = 1.0376$

For IVA Modules: $K = \frac{\text{1099.2 Seconds (Zero-g in S.S.)}}{\text{878 Seconds (One-g in S.S.)}} = 1.2519$

B. From Zero-g in Shirtsleeves and Foot Restraints to Zero-g in Pressure Suit with No Foot Restraints

For EVA Black Boxes: $K = \frac{\text{237.6 Seconds (Zero-g P.S.)}}{\text{138 Seconds (Zero-g S.S.)}} = 1.732$

For IVA Modules: $K = \frac{\text{2648.4 Seconds (Zero-g P.S.)}}{\text{1099.2 Seconds (Zero-g S.S.)}} = 2.4085$

C. From One-g Shirtsleeves to Zero-g Pressure Suit Without Foot Restraints

For EVA Black Boxes: $K = \frac{\text{237.6 Seconds (Zero-g P.S.)}}{\text{133 Seconds (One-g S.S.)}} = 1.7865$

F For IVA Modules: $K = \frac{\text{2648.4 Seconds (Zero-g P.S.)}}{\text{878 Seconds (One-g S.S.)}} = 3.0164$

Column 12 - Self-Test or Stimuli Requirements

Information in this column summarizes built-in or external equipment that is essential to the location of LRU level faults. Information in parentheses indicates external equipment. All other information indicates equipment that is built into the element. An external stimulus generator has been specified for use with the Data Acquisition units. It is wired to Data Acquisition equipment and is controlled by the DMS.

Column 13 - Mechanical Adjustments

This column is an estimate of the time required for periodic mechanical adjustments to maintain reliable operation. Mechanical adjustment may be needed for any electromechanical device that is subject to wear or change in setting after repeated operations. The adjustments will be performed on a periodic basis as part of the preventive maintenance procedures.

Column 14 - Calibration Requirements

Information in these columns is an estimate of the expected calibration time for analog and electromechanical components. They offer a measure of the astronaut involvement in preventive maintenance and set up procedures. They also indicate the need for design approaches that will minimize both mechanical adjustments and calibration requirements. Magnetic disc and tape units are prime examples.

The sum of Columns 12 and 13 identifies minimum astronaut involvement in preventive maintenance and calibration procedures. They may help to justify the need for lower levels of DMS fault isolation software that will minimize astronaut involvement.

Column 15 - Margin Check Requirements

The purpose of this column is to identify those LRUs or SRAs that might require periodic variation of electrical or mechanical parameters in order to determine amount of degradation. An indication of the level of degradation is also an indication of remaining useful life. This information may be applicable for planning adjustment and calibration schedules, and it may be of value to the logistics planning procedure because it is a prediction of time to failure.

The value of knowing the degree to which a device has degraded must be equated to its cost in terms of power, weight, and volume of equipment and the astronaut time required to perform the check.

Column 16 - Hazards

Information in this column should indicate the hazards involved in replacement of LRU or in performing fault isolation or repair at the SRA level. The hazards identified will help to define the safe handling and repair levels for all types of assemblies. Another result of identifying hazards should be the definition of design requirements that would minimize accidents and reduce the complexity of maintenance procedures.

Items to be considered in this column include: Contamination of the environment, high voltage, exposure to rotating equipment, handling of equipment having large weight or volume, exposure to extreme temperatures, and unusual physical effects on the astronaut. The latter item could include strains due to poor light, poor access, or unusually complex procedures.

Subsystem Data Management

Sheet 1

1 Group	2 Line Replaceable Unit/ LRU/SRA	3 Quantity Required	Redundant	Spares	Total	4 No. of Books	5 MTBF (Hrs) est.	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On Line)	9 Manual Fault Isolation (On Line)	10 Operational Recovery Scheme	11 MTTR (Hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustments	14 Calibration Req's Pre-Installation	Periodic	Manual	Automatic	15 Margin Check Requirements Trend Analysis	16 Hazards
Computer	Data Bus Controller (DBC)	2	2		4	1	200K	20 sec	Yes	Execute Self Check Routine	None	Reconfiguration Remove & Replace (R&R) Keyboard Entry Req'd to Reset Configuration - Register & Initiate Verification Test	-	Bite Parity Diagnostic	None	No	No	No	No	None Equipment Rack Temp. 4 Meas. Sample Every 3 Minutes Auto Calibrate Every 3 Months	None
	Modem	1	-	-	-	-	-	-	No	N/A	N/A		-		None	No	No	No	No		None
	Buffer	1	-	-	-	-	-	-	No	N/A	N/A		-		None	No	No	No	No		None
	Timing & Logic	1	-	-	-	-	-	-	No	N/A	N/A		-		None	No	No	No	No		None
	Power Supply	1	-	-	-	-	-	-		4 Monitor Signals											
	Data Bus Switch (DBS) Matrix	1			1	1	Int. Red		Yes (Fail Soft)	Execute DBC Self Check Routine	Replace Data Bus I/O Also	Operate in Degraded Mode till R&R Opportunity		Part of DBC Self Check Routine	No	No	No	No	No	None See DBC	None
	CMD Buffer	6			6	-	-	-	No	-	None	-	-	-	-	No	No	No	No		-
	CMD Decoder & Logic	6			6	-	-	-	No	-	-	-	-	-	-	No	No	No	No		-
	Switching Assembly	1			1	-	-	-	No	-	-	-	-	-	-	No	No	No	No		-
	Power Supply									2 Monitor Signals	•										
	Memory Switch Matrix (Same as DBS Matrix)	1			1	1	Int. Red			Write Logic & Control (L&C) Pattern & Compare	•	No		Part of Shared Memory Diagnostic							
	Data Bus I/O (CPU)	6			6	½ ea	15K		CPU Load is Transferred to Other CPU's CPU Containing Faulty LRU becomes Inactive	Execute DBC Self Check Routine	Replace Data Bus Switch Matrix Also	Reconfigure System Then R&R		Part of DBC Self Check Routine Parity Checks All incoming Data	No	No	No	No	No	None See DBC	None
	Buffer	4			24	-	-	-		-	-	-	-		-	No	No	No	No		-
	Parity Check	4			24	-	-	-		-	-	-	-		-	No	No	No	No		-
	Logic & Control	1			6	-	-	-		-	-	-	-		-	No	No	No	No		-
	Memory I/O (Shared) (CPU) (Same as Data Bus I/O)	6			6	1	15K			Write Logic & Control Pattern & Compare	•	Same		Part of Shared Memory Diagnostic							
	Logic & Control (CPU)	6			6	3	125K	20 sec		Execute Self Check Routine Detected by Internal Parity of 'Watch Dog' Violation	None	Reconfigure System Then R&R		Pattern Gen Timer Parity Error Detection 'Watch Dog' Error Routine	No	No	No	No	No	None See DBC	None
	Arithmetic	6			36	1	-	-			-	-	-		-	No	No	No	No		-
	Program Control	6			36	1	-	-			-	-	-		-	No	No	No	No		-
	Pattern Generator	6			36	1	-	-			-	-	-		-	No	No	No	No		-

•Fault Isolation to a Single LRU is not Practical Automatically

Maintenance Requirements Analysis (Cont.)

Subsystem Data Management **Sheet 2**

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	In place (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
Com-puter	Data Bus Controller (DBC) Modem Buffer Timing & Logic	None Access to Test Points-Training-Documentation Transport Maintaining Position of Tools, Test Equipment, M Aids and Spare Assem-blies	Bit Control Data Check Training Document-ation M Fixtures	DMS Software DMS Software Data Pattern Control M Documen-tation	M Documentation Hook Up Pro-cedures Test Point Wave Form Analy-sis	R&R Tools Meters-Scopes M aids-Viewer or Display Extender on Slides if Test Points not Available on LRU Front	R&R Tools Same M Fix-tures R&R Tools Assem-blie Tools	1. Min & Max Distance from Walls, Floor, Ceiling for Access 2. Front Panel Test Points 3. Personnel, Tools, Equipment, Positioners Restraints Transport Devices 4. Multi-purpose Test Equipment 5. Hand-Power Tool Design 6. M Aids (How & Software) 7. LRU Interface Inter-locks 8. Pwr Interlocks	Multi-Use Power Source Data Gene-rators Signal Signal Gene-rators Displays
	Data Bus Switching Matrix (DBS) CMD Buffer CMD Decoder & Logic Switching Assembly	Difficult to Isolate to this LRU-R&R Activity takes Entire DMS off Off-Line Same as DBC	Same as DBC	DMS Software Same as DBC	Same as DBC	Same as DBC	Same as DBC	Same as DBC	Same as DBC
	Memory Switch Matrix (Same as DBC Matrix)	Same as Above	Same	Same as Above	Same as Above	Same as Above	Same as Above	Same as Above	Same as Above
	Data Bus I/O (CPU) Buffer Parity Check Logic & Control	None Same as DBC	Same as DBC	DMS Software Same as DBC	Same as DBC	Same as DBC	Same as DBC	Same as DBC	Same as DBC
	Memory I/O (Same as Data Bus I/O								
	Logic and Control (CPU) Arithmetic Program Control Pattern Generator	None Same as DBC	Same as DBC + Program Data Con-trol and Display	DMS Software Same as DBC	Same as DBC	Same as DBC	Same as DBC + Remain-der of CPU, Storage, Program & Data Entry-Data Check	Same as DBC	Same as DBC + Pro-gram Cycle Control Design

M = Maintenance

Subsystem Data Management

Sheet 1

1	2	3				4	5	6	7	8	9	10	11	12	13	14				15	16
Group	LRU/SRA	Quantity					MTBF (Hrs) est.			Fault Isolation Scheme (On Line)	Manual Fault Isolation (On Line)	Operational Recovery Scheme	MTTR (Hrs)	Self Test or Stimulus Req's		Calibration Req's				Margin Check Require-ments Trend Analysis	Hazards
		Required	Redundant	Spares	Total	No. of Books		Critical Downtime Limit	Software Reconfigurable						Mechanical Adjustman	Pre-Installation	Periodic	Manual	Automatic		
Com-puter	Dedicated Memory (CPU) Memory Element Address-Decoder	6 6 1	-	-	6 6 1	 2 -	125K	20 sec	Part of CPU See L&C	Execute L&C Self Check Routine Write L&C Pattern Read & Compare	None	Reconfig-ure System Then R&R		Part of Self Check Routine	No	No	No	No	No	None See DBC	None
	Power Supply (CPU) Low Voltage Regulator Card Common Power Control	1 6 4	 - -	 - -	1 6 6	1 - -	250K	20		6 Signals Are Hard Wired to Interrupt CPU	None	Same as Above		None						None See DBC	Weight (Mass) High Voltage
	Shared Memory-Electronics Section I/O Logic Control Circuitry (etc.)	15	-	-	15	15	500K	20	Yes Sys Only	Write L&C Pattern in-to Memory Read & Compare	Verify Contin-uity of Storage Med-ium	Switch to Alternate Shared Memory Then R&R		None	No	No	No	No	No	None See DBC	None
	Shared Memory-Mechanical Assemblies Disc Drives Tape Transports (etc.)	15	-	-	15	N/A	10K	20	Memory allocation table is changed to inactivate the bad memory LRU. Status displayed to crew.	Write L&C Pattern in-to Memory Read & Compare	Initiate Mech-ical Sec-tion Test	Same as Above		None						None See DBC	Rotating Equip-ment
	Memory Elements Solid State Memory Disc. Magnetic Tape Reels	 6 6 3	 - - -	 - - -	 6 6 3		 750K 10K 10K	20 sec		Write L&C Pattern in-to Memory Read and Compare	Verify Contin-uity of Storage Medium	Same as Above		None	No	No	No	No	No	None See DBC	None
	Shared Memory - Power Supplies	15			15	15		20 sec		12 Signals Main 30 Signals Aux.	Monitor Power Output Indicator Check Leads Connec-tors etc.	Same as Above		None						None See DBC	Voltage
Bulk Data Stor-age	Data Bus Terminal (DBT) Modem Buffer Logic & Control Interface Power Supply	2 1 1 1 1	- - - - -	- - - - -	50 50 50 50 50	1 - - - -	200K	20 sec in Critical App 1 Hr. Elsewhere	Yes	Execute Self Test Routine 50 Moni-tor Signals	No Res-ponse Check Data Bus & DBT Connec-tions	Use Secondary Path-Dis-play to Crew then R&R		Routes Calibrat-ed Signal thru it-self then to the CPU	No - - - - -	No - - - - -	No - - - - -	No - - - - -	No - - - - -	None Sample Equipment Rack Temp. Every 3 Minutes 50 Signals Auto Cali-brate Every 3 Months	None

Subsystem Data Management

Sheet 2

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
Computer	Dedicated Memory Memory Element Address Decoder	Same as DBC + Loss of Memory Disables Whole LRU	Same as DBC + Data Generation and Cycle Control Display	Self Check Routine - See Column 8 and DBC	Same as DBC	Same as DBC	Same as DBC + Data Entry Date Check & Address Control	Same as DBC	Same as DBC + Data Entry Display and Control
	Power Supply Low Voltage Regulator Card Common Power Control	Same as DBC + Safe use of Test Equipment	Power Loads Level + Ripple Test	DMS Output M Documentation Load Control	Same as DBC	Same as DBC + Dummy Load	Same as DBC + Dummy Load	Same as DBC + Load Simulators	Same as DBC + Load Simulators
	Shared Memory-Electronic Section	Same as DBC	Same as DBC	DMS Software + Same as DBC	Same as DBC	Same as DBC	Same as DBC	Same as DBC + Unique Design and Software, Requirements to Allow Sharing of CPU for Operations and Maintenance	Same as DBC + Data Entry Display and Control
	Shared Memory-Electronic Assemblies	Access Safe Use of Tools and Test Equipment	•Access •Safe Use of Tools and Test Equip-	Same as DBC	Same as DBC	Same as DBC + Calibration Alignment Tools & Fixtures	Same as DBC + Calibration Alignment Tools & Fixtures	Same as Above	Same as Above
	Memory Elements	None	Same as DBC + Data Generation and Cycle Control Display	Same as DBC + DMS Software	Same as DBC	Same as DBC	Same + Address Data Entry and Display Capability	Same as Above	Same as Above
	Shared Memory-Power Supplies	Same as CPU Pwr Supply	Same as CPU Pwr Supplies	Same as CPU Pwr Supplies	Same as CPU Pwr Supplies	Same as CPU Pwr Supplies	Same as CPU Pwr Supplies	Same as CPU Pwr Supply	Same as CPU Pwr Supply
Bulk Storage Data	Data Bus Terminal (DBT) Modem Buffer Logic and Control (L&C) Interface	Good Electrical Interface & Accessibility	Electrical Interfaces Training Documentation M Fixtures	Self Check Routine	Self Check Routine + Documentation	R&R Tools	Electrical Interfaces Tools Fixtures	Accessibility Quick Disconnect	Multi-Use Power Source Data Generator Signal Generator Displays

M = Maintenance

Subsystem Data Management

Sheet 1

1	2	3				4	5	6	7	8	9	10	11	12	13	14				15	16
Group	LRU/SRA	Quantity				No. of Books	MTBF (Hrs) est.	Critical Downtime Limit	Software Reconfigurable	Fault Isolation Scheme (On Line)	Manual Fault Isolation Req's (On Line)	Operational Recovery Scheme	MTTR (Hrs.)	Self Test or Stimulus Req's	Mechanical Adjustments	Calibration Req's				Margin Check Require-ments Trend Analysis	Hazards
		Required	Redundant	Spares	Total											Pre-Installation	Periodic	Manual	Automatic		
Bulk Data Stor-age (Cont)	Digital Buffer and Control Command Decoder Buffer Logic & Control (L&C) I/O Circuits	1 2 2 1 2	· · · · ·	· · · · ·	1 2 2 1 2	2 · · · ·	500K	24 Hrs	Change Allocation Table · Identify Recoverable Contents · Allocate other Available Space · Copy Data From Alternate Source · Update Configuration Control Register.	Execute DBT Self Check Routine Execute L&C Pat-tern into Buffer Read & Compare	None	None		Stores Test Pat-tern Read Out on Command	No	No	No	No	No	None None	None
	Record & Response Electronics Read/Write Amplifiers Power Regulator & Supply	1 4 1	· · ·	· · ·	1 4 1	1 · ·	500K	24 Hrs		Execute L&C Pat-tern into Storage Read & Compare 2 Monitor Signals	Change Tape Reels	Switch to Alter-nate Channel		Part of DBT Self Check Routine	No	No	No	No	No	None None	None
	Transport Switch Matrix	1	·	·	1		Int. Red	24 Hrs		Execute DBT Self Test Routine	None	Use Alternate Channel		Same	No	No	No	No	No	None None	None
	Controller Switch Matrix	1	·	·	1		Int. Red	24 Hrs		Same as Above	None	Use Alternate Channel		Same	No	No	No	No	No	None None	None
	Tape Transports Drive Motor Electro-Mechanical Assembly Power Supply	4			4	- - · ·	10K	24 Hrs		Same as Above 4 Monitor Signals	None	Use Alternate Medium		Same	No Yes No	No No No	No Yes No	No Yes No	No No No	None None	None
	Tape Transport Controller Read/Write Control Power Supply	2			2		250K	24 Hrs		Same as Above 4 Monitor Signals	None	Same		Same	No	No	No	No	No	None None	None
	Power Supply Regulator Cards Distribution Circuitry	1			1		250K	20 sec		If All Above Tests Fail Indicate Manual Help Required	Check Pwr Out and Distribu-tion	Use Alternate Medium (Storage)			No	No	No	No	No	None None	None
Data Acqui-sition	Data Bus Terminal (DBT) (Same as DBT Listed) under Bulk Data Storage)	6			50		200K	20 sec	Change the DBC/DBT/RDAU Table to Inactivate Bad LRU	Execute DBT Self Check Routine	Check DBT & Data Bus Connec-tions	None		Cali-brated Signal	No	No	No	No	No	None None	None
	Remote Data-Acquisition Unit (RDAU) Timing-Mux-A/D Converter Programmer-Limit Memory Output Register	48			133		1000 K	20 sec		Execute RDAU Self Check Routine	None	None Secondary Path Available		Bit	No	No	No	No	No	None None	None
	Stimuli Generation Unit (SGU) Power Supply				42		1000 K	20 sec		Execute SGU Out-put Check 42 Monitor Signals	Check Stimu-lation Loop & Sensors	None		Monitor Test Out-put with Known Good RDAU	No	No	No	No	No	None None	None

Subsystem Data Management

Sheet 2

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
Bulk Data Storage	Digital Buffer and Control (DBC) Command Decoder Buffer Logic & Control (L&C) I/O Circuits	Electrical Interfaces and Accessibility	Electrical Interfaces Training Documentation M Fixtures	Self Check Routine L&C Pattern Check	Same as Inplace + Documentation	Removal & Replacement (R&R) Tools	Electrical Interface Tools Fixtures	Same as DBC	Multi-Use Pwr Source Data Gen Signal Gen Displays
	Record & Reproduce Electronics Read/Write Amplifiers Power Regulator	Same	Same	L&C Pattern Check	Same	Same	Same	Same	Same
	Transport Switch Matrix	Record & Reproduce Activity Disables all of Bulk Storage	Same	DBT Self Test Routine	Same	Same	Same	Same	Same
	Controller Switch Matrix	Same as Above	Same	Same	Same	Same	Same	Same	Same
	Tape Transports Drive Motor Electro-Mechanical Assembly	Read Head Cleaning and Adjustments Accessibility	Same	Same	Same	Same	Same	Same	Same
	Tape Transport Controller Read/Write Control	Electrical Interfaces and Accessibility	Same	Same	Same	Same	Same	Same	Same
	Power Supply Regulator Cards Distribution Circuitry	Same	Same	Same	Same	Same	Same	Same	Same
Data Acquisition	Data Bus Terminal Same as DBT listed under Bulk Data Storage	Good Electrical Interfaces and Accessibility	Electrical Interfaces Training Documentation M Fixtures	Self Check Routine	Self Check Routine + Documentation	R&R Tools	Electrical Interfaces Tools Fixtures	Accessibility Quick Disconnect	Multi-Use Pwr Source Data Generator Signal Generator Displays
	Remote Data Acquisition Unit	Same	Same	Self Test Routine	Same	Same	Same	Same	Same
	Stimulation Generation Unit (SGU)	Same	Same	SGU Command Routine	Same	Same	Same	Same	Same

Maintenance Requirements Analysis (Cont.)

Subsystem Data Management

Sheet 1

1 Group	2 LRU/SRA	3 Quantity: Required	Redundant	Spares	Total	4	5 MTBF (Hrs) est	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On Line)	9 Manual Fault Isolation Req's (On Line)	10 Operational Recovery Scheme	11 MTTR (Hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustments	14 Calibration Req's: Pre-Installation	Periodic	Manual	Automatic	15 Margin Check Requirements Trend Analysis	16 Hazards
Command Control Display	Data Bus Terminal (DBT) (Same as DBT Listed Under Bulk Data Storage)	2	2	-	50		200K		Yes	Execute DBT Self Check Routine	Check DBT & Data Bus Connections if No Response	Use Secondary Path Display Status to Crew		None	No	No	No	No	No	None Sample Equipment Rack Temp. Every 3 Minutes 6 Measurement	None
	Stimuli Generation Unit (SGU) (Same as SGU Listed Under Data Acquisition)	2	2	-	42		1000K		Yes	Execute SGU/CBC Output Check Routine	None	Same		None	No	No	No	No	No	Auto Calibrate Every 3 Months —— Same	None
	Display Control & Buffer	2	-	-	2		20K		No	Execute Man/Auto CPU Display Pattern Test from Redundant Controls	Monitor Display in Question	R&R		Yes	No	No	No	No	No	Same	None
	Display Switch Matrix (DSM)	2	-	-	2		Int. Red		No	Execute Manual/Auto Digital Feedback Test Routine	Initiate Auto Monitor Test	R&R		None	No	No	No	No	No	Same	None
	Refresh Buffer (RB)	2	-	-	2		80K		No	Execute Video/CRT Test with CCTV or Video Tape	Execute Test and Monitor Results	R&R		None	No	No	No	No	No	Same	None
	Display Control Power Supply	8	-	-	8		50K		No	Same as RB 2 Monitor Signals	Same as Refresh Buffer	R&R		None	No	No	No	No	No	Same	None
	CRT Display Assembly	8	-	-	8		100K		No	Same as DSM	Same as DSM	R&R		None	No	No	No	No	No	Same	CRT Implosion
	Warning Annunciator Assy	200	-	-	200		2000 K		No	Same as DSM	Monitor Annunciator Panel	R&R		None	No	No	No	No	No	Same	None
	Caution Display Assembly	50	-	-	50		2000 K		No	Same as DSM	Monitor Display	R&R		None	No	No	No	No	No	Same	None
	Alpha-Numeric Display	150	-	-	150		2000 K		No	Execute Man/Auto Digital Feedback Test Routine	Monitor Display	R&R		None	No	No	No	No	No	Same	None
	Status Light Assembly	200	-	-	200		3000 K		No	Same as DSM	Monitor Status Display	R&R		None	No	No	No	No	No	Same	None

Maintenance Requirements Analysis (Cont.)

Subsystem Data Management **Sheet 2**

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
Com-mand Control Display	Data Bus Terminal Same as DBT Listed under Bulk Data Storage	Good Electrical Interfaces	Electrical Interfaces Training Documen-tation M Fixtures	Self Test Routine	Self Test Routine Documentation	R&R Tools	Data Bus In-terface Tools Fixtures	Accessibility Quick Disconnect	Multi-Usage Power Source Data Gene-rators Signal Generators Displays
	Stimuli Generation Unit Same as SGU Listed under Data Acqui-sition	Good Electrical Interfaces	Same	Self Test Routine	Self Test Routine Documentation	R&R Tools	Data Bus Interface Tools Fixtures	Same	Same
	Display Control & Buffer	Same + Accessibility	Same	Self Test Routine	Documentation	R&R Tools	Electrical Interfaces Tools Fixtures	Same	Same
	Display Switch Matrix	Same as Above	Same	Self Test Routine	Same	R&R Tools	Same	Same	Same
	Refresh Buffer	Same	Same	Video CRT Test with CCTV or Video Tape	Documentation + Video CRT Test with Video Tape	R&R Tools	Same	Same	Same
	Display Control Power Supply	Same	Same	Self Test Routine	Documentation	R&R Tools	Same	Same	Same
	CRT Display Assembly	Same	Same	None	Same	R&R Tools	Same	Same	Same
	Warning Annunciator Assembly	Same	Same	Digital Feed-back Test Routine	Same	R&R Tools	Same	Same	Same
	Caution Display Assembly	Same	Same	Digital Feed-back Test Routine	Same	R&R Tools	Same	Same	Same
	Alpha-Numeric Display	Same	Same	Digital Feed-back Test Routine	Same	R&R Tools	Same	Same	Same
	Status Light Assembly	Same	Same	Digital Feed-back Test Routine	Same	R&R Tools	Same	Same	Same

Maintenance Requirements Analysis (Cont.)

Subsystem Data Management — Sheet 1

1	2	3				4	5	6	7	8	9	10	11	12	3	14				15	16
Group	LRU/SRA	Quantity				No. of Books	MTBF (Hrs)	Critica Downtime Limit	Software Reconfigurable	Fault Isolation Scheme (On Line)	Manual Fault Isolation Req's (On Line)	Operational Recovery Scheme	MTTR (Hrs)	Self Test or Stimulus Req's	Mechanical Adjustments	Calibration Req's				Margin Check Require-Ments Trend Analysis	Hazards
		Required	Redundant	Spares	Total											Pre-Installation	Periodic	Manual	Automatic		
Com-mand Control Display (Cont)	Dedicated Displays	150	-	-	150		3000K		No	Initiate Test	Monitor Result	R&R		None	No	No	No	No	No	None See DBT this Group	None
	Command Buffer and Control (CBC)	2	-	-	2		500K		No	Execute Command Buffer and Control Self Check Routine	None	R&R		Yes	No	No	No	No	No	Same	None
	Digital Multiplexor	2		-	2		500K		No	Execute SGU Digital Feedback Test Routine	None	R&R		None	No	No	No	No	No	Same	None
	Hand Controller Assembly (HCA)	2		-	2		300K		No	Execute Man/Auto CPU Display Pattern Test from Redundant Controls	Monitor Display	R&R		None	No	No	No	No	No	Same	None
	Mode Select Switch Assembly	8	-	-	8		200K		No	Same as HCA	Same as HCA	R&R		None	No	No	No	No	No	Same	None
	Multi-Function Switch Assembly	300	-	-	300		1000K		No	Same as HCA	Same	R&R		None	No	No	No	No	No	Same	None
	Mono-Function Switch Assembly	600	-	-	600		1500K		No	Same as HCA	Same	R&R		None	No	No	No	No	No	Same	None
	Computer Keyboard Assembly	2		-	2		100K		No	Same as HCA	Same	R&R		None	No	No	No	No	No	Same	None
	Discrete Controls	2	-	-	2		200K		No	Operate Control	Monitor Response	R&R		None	No	No	No	No	No	Same	None
	Microfilm Viewer Assembly	2		-	2		100K		No	Execute Man/Auto Microfilm Test	Initiate and Monitor Display	R&R		None	No	No	No	No	No	Same	None
	Microfilm Viewer Control and File Assembly Power Supply	2	-	-	2		100K		No	Same as MVA 4 Monitor Signals	Same as MVA	R&R		None	No	No	No	No	No	Same	None

Subsystem Data Management

Sheet 2

1	2	17		18				19	
		Problems		Maintainence Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
Com-mand Control (Cont.)	Dedicated Displays	Good Electrical Interfaces Accessibility	Electrical Interfaces Training Documen-tation M Fixtures	Documentation	Documentation	R&R Tools	Electrical Interfaces Tools Fixtures	Accessibility Quick Disconnect	Multi-Use Power Source Data Gene-rators Signal Generator
	Command Buffer & Control	Same	Same	Self Check Routine	Self Check Routine + Documentation	R&R Tools	Same	Same	Same
	Digital Multiplexor	Same	Same	SGU Digital Feedback Test	SGU Digital Feedback Test + Documentation	R&R Tools	Same	Same	Same
	Hand Controller Assembly	Same	Same	CPU Test Pattern	CPU Test Pattern Documentation	R&R Tools	Same	Same	Same
	Mode Select Switch Assembly	Same	Same	Same	Same	R&R Tools	Same	Same	Same
	Multi-function Switch Assembly	Same	Same	Same	Same	R&R Tools	Same	Same	Same
	Mono-function Switch Assembly	Same	Same	Same	Same	R&R Tools	Same	Same	Same
	Computer Keyboard Assembly	Same	Same	Same	Same	R&R Tools	Same	Same	Same
	Discrete Controls	Same	Same	Documentation	Documentation	R&R Tools	Same	Same	Same
	Microfilm Viewer Assembly	Same	Same	Microfilm	Microfilm + Documentation	R&R Tools	Same	Same	Same
	Microfilm Viewer Control and File Assembly Power Supply	Same	Same	Same	Same	R&R Tools	Same	Same	Same

Subsystem Data Management

Sheet 1

1	2	3				4	5	6	7	8	9	10	11	12	13	14				15	16
Group	LRU/SRA	Quantity				No. of Books	MTBF (Hrs) est.	Critical Downtime Limit	Software Reconfigurable	Fault Isolation Scheme (On Line)	Manual Fault Isolation Req's (On Line)	Operational Recovery Scheme	MTTR (Hrs)	Self Test or Stimulus Req's	Mechanical Adjustments	Calibration Req's				Margin Check Require-ments Trend Analysis	Hazards
		Required	Redundant	Spares	Total											Pre-installation	Automatic	Periodic	Manual		
Com-mand Control Display (Cont)	Analog Interface Unit Power Supply	2	-	-	2		300K		No	Execute Remote Intercom Test 4 Monitor Signals	Initiate and Mon-itor Result	R&R		None	No	No	No	No	No	None None	None
	Channel Select and Analog Control	2	-	-	2		500K		No	Execute Local Inter-com, Audio Tape and Video Tape CRT Tests	Initiate and Mon-itor Result	R&R		None	No	No	No	No	No	None None	None
	CCTV Panel Assembly	2	-	-	2		80K		No	Execute CCTV/CRT Test	Initiate and Mor-itor Result	R&R		None	Yes	No	No	No	No	None None	None
	Intercom Control Panel (ICP)	2	-	-	2		500K		No	Execute Remote Intercom Test	Initiate and Mon-itor Result	R&R		None	No	No	No	No	No	None None	None
	Audio Tape Assembly	2	-	-	2		70K		No	Same as ICP	Same as ICP	R&R		None	No	No	No	No	No	None None	None
	Video Tape Assembly	2	-	-	2		15K		No	Execute Local Video Tape/ CRT Test	Initiate and Mon-itor Display	R&R		None	No	No	No	No	No	None None	None
	Illumination Control Assembly	2	-	-	2		200K		No	Visual Check	Visual Check	R&R		None	No	No	No	No	No	None None	None
	CCDC Power Supplies Audio/Visual General Console	2	-	-	2		200K		No	4 Monitor Signals 4 Monitor Signals	Visual Check on Indica-tors	R&R		None	No	No	No	No	No	None None	None
Port-able Control and Display	Data Bus Terminal Same as DBT Listed Under Bulk Data Storage	4	-	-	50		200K		No	Execute DBT Self Check Routine	Check DBT and Data Bus Con-nections	Use Another Unit		Route Calibra-tion thru Itself then to CPU	No	No	No	No	No	None Sample Equipment Rack Temp-erature	None
	Display Assembly (DA)	4	-	-	4		100K		No	Execute CPU Test Pattern - Check from Local Key-board the Aux. Plug Function	Initiate and Mon-itor Results	Same		None	No	No	No	No	No	None None	None
	Computer Keyboard Assembly Hand Controller (optional) Multi-Function Switch (Optional) These LRU's Are Covered Under Command/Control and Display	4 4 4	- - -	- - -	4 4 4		100K 300K 300K		No No No	Same as DA	Same as DA	Same		None	No	No	No	No	No	None None	None
	Power Supply	4	-	-	4		200K		No	Visual Check of Indicators	Check Indicator	R&R		No	No	No	No	No	No	None None	None

Maintenance Requirements Analysis (Cont.)

Subsystem Data Management

Sheet 2

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
Command Control Display (Cont.)	Analog Interface Unit Power Supply	Good Electrical Interfaces + Accessibility	Electrical Interfaces Training Documentation M Fixtures	Remote Intercom Test	Remote Intercom Test + Documentation	R&R Tools	Electrical Interfaces Tools	Accessibility Quick Disconnect	Multi-Use Pwr Source Data Generators Signal Generators Displays
	Channel Select and Analog Control	Same	Same	Local Intercom /Audio Tape & Video Tape Tests	Same as Inplace + Documentation	R&R Tools	Same	Same	Same
	CCTV Panel Assembly	Same	Same	CCTV/CRT Test	Same	R&R Tools	Same	Same	Same
	Intercom Control Panel	Same	Same	Remote Intercom Test	Same	R&R Tools	Same	Same	Same
	Audio Tape Assembly	Same	Same	Same	Same	R&R Tools	Same	Same	Same
	Video Tape Assembly	Same	Same	Local Video Tape/CRT Test	Same	R&R Tools	Same	Same	Same
	Illumination Control Assembly	Same	Same	None	None	R&R Tools	Same	Same	Same
	CCDC Power Supplies Audio & Video General Console	Same	Same	None	Documentation	R&R Tools	Same	Same	Same
Portable Control and Display	Data Bus Terminal	Same	Same	Self Check Routine	Self Check Routine + Documentation	R&R Tools	Same	Same	Same
	Display Assembly	Same	Same	CPU Test Pattern	Same as Inplace + Documentation	R&R Tools	Same	Same	Same
	Computer Keyboard Assembly Hand Controller Multi-function Switch	Same	Same	Same	Same	R&R Tools	Same	Same	Same
	Power Supply	Same	Same	None	Documentation	R&R Tools	Same	Same	Same

Maintenance Requirements Analysis (Cont.)

Subsystem Data Management

Sheet 1

1 Group	2 LRU/SRA	3 Quantity: Required	3 Quantity: Redundant	3 Quantity: Spares	3 Quantity: Total	4 No. of Books	5 MTBF (Hrs)	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On Line)	9 Manual Fault Isolation Req's (On Line)	10 Operational Recovery Scheme	11 MTTR (Hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustments	14 Calibration Req's: Pre-Installation	14 Calibration Req's: Periodic	14 Calibration Req's: Manual	14 Calibration Req's: Automatic	15 Margin Check Requirements Trend Analysis	16 Hazards
GN&C Preprocessors	Data Bus Terminal Same as DBT Listed under Bulk Data Storage	2	-	-	50		200K	20 sec	Yes	Execute DBT Self Check Routine	None	Use Secondary Path Display Status to Crew		Calibrated Signal Thru Self to CPU	No	No	No	No	No	None Sample Equipment Rack Temp	None
	Preprocessor	2	-	-	2		30K		Yes	Execute Self-Check Routine 5 Monitor Signals	None	Switch to Alternate Pre-Processor		Yes	No	No	No	No	No	None None	None
	Power Supply																				

Subsystem Data Management

Sheet 2

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Comples	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
GN&C Preprocessors	Data Bus Terminal	Electrical Interfaces and Accessibility	Same as Inplace + Training Documentation M Fixtures	Self Check Routine	Self Check Routine + Documentation	R&R Tools	Electrical Interfaces Tools Fixtures	Accessibility Quick Disconnect	Multi-Use Power Source Data Generator Signal Generator
	Preprocessor Power Supply	Same as Above	Same	Self Test Program	Self Test Program + Documentation	R&R Tools	Same	Same	Same

Subsystem R. F. Communications

Sheet 1

1 Group	2 LRU/SRA	3 Quantity: Required	3 Quantity: Redundant	3 Quantity: Spares	3 Quantity: Total	4 No. of Books	5 MTBF (Hrs) est.	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On Line)	9 Manual Fault Isolation Req's (On Line)	10 Operational Recovery Scheme	11 MTTR (Hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustments	14 Calibration Req's: Pre-Installation	14 Calibration Req's: Periodic	14 Calibration Req's: Manual	14 Calibration Req's: Automatic	15 Margin Check Requirements Trend Analysis	16 Hazards
Free-Flying Module (FFM)	S-Band Video Reciever (S-BVR) FM Detector AGC Detector Mixers Filters	10	-	-	10	1	715K		No	Issue Stimulus Command and Monitor Response	Initiate Periodic Checks and Monitor Response	Use Functionally Redundant System		-Pri. Pwr. Control -AGC * -Modulation Input * *Generated Internal to RFCS	None	No	No	No	No	None Sample AGC on Once/Day Basis During a Duty Cycle Compare with Average of Last 30 Samples	Total Qty Non-Critical
	Video Receiver Modem Harmonic Generator Mixer Fixed Tuned Amplifier Variable Tuned Amplifier Lo-Pass Filter	10	-	3	13	1	286K		No	Same	Initiate Test and Monitor Response	Same		-Pri. Pwr. Control -Modulation Input * -Video Channel Select * *Generated Internal to RFCS	None	No	No	No	No	None None	Same
	S-Band Receiver (S-BDR) Phase & Amplitude Detectors Voltage Controlled Oscillator Mixer Frequency Multipliers Filters	10	-	3	13	1	642K		No	Same	Initiate Test and Monitor Response	Same		-Pri.Pwr. Control -AGC * -Modulation Input * *Generated Internal to RFCS	None	No	No	No	No	None Sample AGC Level Once/Day. Compare with Average of Last 30 Samples	Same
Data Relay Satelite System (DRSS)	S-Band PM Receiver (Similar to S-Band Data Receiver)	2	-	-	2	1	642K		No	Same	Operation Monitor	Same as S-BVR		Same as S-BDR	None	No	No	No	No	None Sample AGC Level once/hour during duty cycle-Compare with average of last 48 Samples-Retain daily ave. for 3 Months	Same
	Ku-Band FM Exciter 80mHz Crystal Oscillator Frequency Multipliers Filters Amplifiers FM Modulator	2	-	-	2	1	920K		No	Issue Stimulus Command and Monitor Response	Initiate Test and Monitor Response	Use Functionally Redundant System		-Pri Pwr Control -RF Pwr Modulation Input (RFCS Internal Signal)	None	No	No	No	No	None Sample AGC Level Once/Hour During Duty Cycle Compare with Average of Last 48 Samples Retain Daily Average for 3 Months	Total Qty Non-Critical

* REF Meas/Stim List When Available

Maintenance Requirements Analysis (Cont.)

Subsystem R. F. Communications

Sheet 2

1	2	17 Problems		18 Maintenance Requirements				19 Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench	Inplace	Bench	Inplace	Bench	Inplace	Bench
Free Flying Module (FFM)	S-Band Video Receiver FM Detector AGC Detector Mixers Filters	•Good Coax Connection •EMI	• Tuning • Module-to-Module Buildup of Tolerance	Knowledge of Nominal Levels + Allowable Tolerances Mixer-Replacement Procedure	•Tuning or Alignment Procedures •Verification Procedures	•Wrench to Remove Mounting Bolts •Tethers •Replace Mixer Element	• Signal Generator • VTUM • Frequency Meter • Decade Box • Screened Room or Eq. Shielding •Spectrum Analyzer • Electrical Interfaces	Design - Mixers so they are Replaceable	• Part Interchangeability • Part Commonality • Test Point Accessibility and Buffering •Simplify Procedure •Minimize Human Error •Cooling Required
	Video Receiver Modem Harmonic Generator Mixer Fixed Tuned Amplifier Variable Tuned Amplifier Lo-Pass Filter	Electrical Interface •EMI	• Tuning • Alignment	R&R Instructions	Same as Above	Same	Same as Above	Good Voltage Regulation on Power Input	Same as Above
	S-Band Data Receiver Phase and Amplitude Detector Voltage Controlled Oscillator Mixer Frequency Multipliers Filters	Same as Above	Same	Same	Same as Above	Same	Same as Above	Same as Above	Same as Above
Data Relay Satelite System (DRSS)	S-Band PM Receiver (Similar to S-Band Data RCVR)	Same	Same	Same	Same as Above	Same	Same as Above	Same	Same as Above
	Ku-Band FM Exciter 80 mHz Crystal Oscillator Frequency Multipliers Filters Amplifiers FM Modulator	•Test Equipment Interfaces •Accessibility •EMI	• Alignment	Same	Same	Tool to Disconnect Interface with Ku-Band Power Amplifier	•Dummy Load •Frequency Meter •Electrical Interfaces •Spectrum Analyzer •VTUM •FM Signal Generator	Minimize Problem Areas	Same as Above

Subsystem R. F. Communications

Sheet 1

1 Group	2 LRU/SRA	3 Quantity: Required	3 Quantity: Redundant	3 Quantity: Spares	3 Quantity: Total	4 No. of Books	5 MTBF (Hrs)	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On Line)	9 Manual Fault Isolation Req's (On Line)	10 Operational Recovery Scheme	11 MTTR (Hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustments	14 Calibration Req's: Pre-Installation	14 Calibration Req's: Periodic	14 Calibration Req's: Manual	14 Calibration Req's: Automatic	15 Margin Check Requirements Trend Analysis	16 Hazards
DRSS (Cont)	Ku-Band FM Xmitter Modem Harmonic Generators Mixers Fixed Tuned Amplifiers Variable Tuned Amplifiers Filters Modulator Drivers	2	-	-	2	1	119K		No	•Visual •Hearing •Monitor these Functions Under DMS Control •Pri Pwr •Modulation Input/Output	Monitor these Functions During a Duty Cycle · Pri Pwr · Voice Mode · Data Mode · TV Mode · TV Channel Select	Use Functionally Redundant System		•Pri Pwr •Modulation •Voice Data •TV •TV Channel Select	No	No	No	No	No	None None	Same
	S-Band FM Receiver Crystal Oscillator Mixers Amplifiers AGC Detectors Limiters FM Detector	2	-	-	2	1	700K		No	Monitor Functions under DMS Control •Sample AGC Output Once/Minute During Duty Cycle	Operation Monitor	Use Functionally Redundant System		•Pri Pwr •AGC •Modulation Input	None	No	No	No	No	None Sample AGC Level Once per Hour During Duty Cycle Compare with Average 48 Samples - Retail Daily Average for 3 Months	Same
	S-Band FM RCVR Modem Harmonic Generators Tuned Amplifiers Mixers Filters	2	-	-	2	1	700K		No	Under DMS Control Run & Modulation Tests	Operation Monitor	Use Functionally Redundant System		•Pri Pwr •Modution Input •Voice Entertainment Mode •Data Mode •TV Mode •TV Select	None	No	No	No	No	None None	Same
DRSS FFM Common	Ku-Band Power Amplifier Trav. Wave Tube Amplifier Hi-Voltage Pwr Supply Control Circuitry	5	-	-	5	1	70K		No	Run all Checks Under DMS Control •Pri Pwr •Warm-up •RF Pwr Output •VSWR Level	Operation Monitor	Use Functionally Redundant System		•Pri Pwr •PA Warm up Cycle •RF Pwr •VSWR	None	No	No	No	No	None Sample RF Pwr Out Once/Hour During Duty Cycle Compare with Average of last 48 Samples-Retain Daily Average for 3 Months	Total Qty Non-Critical
	Ku-Band PM Exciter 80mHz Oscillator Frequency Multipliers Phase Modulators Subcarrier Oscillator Biphase Modulator	5	-	-	5	1	920K		No	Run all Checks Under DMS Control •Pri Pwr •RF Pwr Output •Modulation Input	Same	Same		•Pri Pwr •RF Pwr Output •Modulation Input	None	No	No	No	No	Same	Same

Maintenance Requirements Analysis (Cont.)

Subsystem R. F. Communications

Sheet 2

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
DRSS (Cont)	Ku-Band FM Transmitter Modem Harmonic Generators Mixers Fixed Tuned Amplifier Variable Tuned Amplifier Filters Modulator Drivers	Electrical Interfaces EMI	• EMI • Module-to-Module Tolerance Build-up • Alignment	Acceptable Parameter Levels	Tuning & Alignment Procedures	•R&R Tools •Tethers	Same as S-Band Video RCVR	Good Voltage Regulation on Power Input	Same as S-Band Video RCVR
	S-Band FM Receiver Crystal Oscillator Mixers Amplifiers AGC Detectors Limiters FM Detectors	Same	Same	Same	Same	Same	Same	Same	Same
	S-Band FM RCVR Modem Harmonic Generators Tuned Amplifiers Mixers Filters	Same	Same	Same	Same	Same	Same	Same	Same
DRSS-FFM Common	Ku-Band Power Amplifier Traveling Wave Tube (TWT) Amplifier Hi-Voltage Pwr Supply Control Circuitry	Same	•Physical Dimensions of TWT •Thermal Cooling Req •Sensitivity to Pwr Supply Changes	Acceptable Parameter Levels R&R Procedures	None	•R&R Tools •Tethers	Recommend TWT and Pwr Supply be mated & Adjusted on the Ground	Wave Guide Quick Disconnect	Design for TWT Replacement in Orbit
	Ku-Band PM Exciter 80 mHz Oscillator Frequency Multipliers Phase Modulators Subcarrier Oscillator Biphase Modulator	Same	•EMI •Module to-Module Tolerance Build-up •Alignment	Same	Tuning and Alignment Procedures	Same	Same as S-Band Video RCVR	Minimize Problem Areas	Same as S-Band Video RCVR

Subsystem R. F. Communications

Sheet 1

1	2	3				4	5	6	7	8	9	10	11	12	13	14				15	16
Group	LRU/SRA	Quantity				No. of Books	MTBR (Hrs)	Critical Downtime Limit	Software Reconfigurable	Fault Isolation Scheme (On-Line)	Manual Fault Isolation Req's (On-Line)	Operational Recovery Scheme	MTTR (Hrs)	Self Test or Stimulus Req's	Mechanical Adjustments	Calibration Req's				Margin Check Require-ments Trend Analysis	Hazards
		Required	Redundant	Spares	Total											Pre-Installation	Periodic	Manual	Automatic		
	S-Band PM Transponder Phase Detectors Sub-Carrier Demod-ulators Voltage Controlled Oscillators Auxiliary Oscillator Frequency Multipliers Phase Modulators	2	.	.	2	1	52K		No	Check the Following* -Pri Pwr Control -Ranging Channel Control/Inhibit -L.O. Control Enable -AGC -RCVR Loop Lock Indicator -RF Pwr -Modulation -VSWR	Initiate Checks and Mon-itor Response	Same		-Pri Pwr -Ranging Control -L.O. Control -AGC -Modu-lation	None	No	No	No	No	None AGC Level Sample 1/day Compare against aver-age of Last 30 Samples RF Pwr Out Sample 1/hr. Compare against Aver-age of Last 48 Samples Retain Daily Average for 30 Days	Same
	S-Band PM Xponder Subcarrier Modulator Demodulators Amplifiers Filters	2	.	.	2	1	?		No	Check the following: -Pri Pwr -1.25mHz -Emergency Voice -70kHz -30kHz	Monitor Bilevel Indica-tors	Use Func-tionally Redundant System		-Pri Pwr -1.25mHz Control -Emer-gency VoiceCtrl -70kHz Control -30kHz Control	None	No	No	No	No	None None	Same
	S-Band Power Amplifier Traveling Wave Tube Amplifier Hi-Voltage Power Supply Control Circuitry	2	.	.	2	1	73.5K		No	Check the* Following -Pri Pwr -Warm-up Cycle -RF Pwr Output -VSWR	Monitor Stimulus Respon ses	Use Func-tionally Redundant System		-Pri Pwr -Warm-up Cycle -RF Pwr	None	No	No	No	No	None RF Pwr Out Sample 1/Hr Compare with Average of Last 48 Samples - Retain Daily Average for 30 Days	Total Qty Non-Criti-
	S-Band FM Exciter 47.5 mHz Local Oscillator FM Modulator Frequency Multipliers Amplifiers Filters Power Supply	2	.	.	2	1	910K		No	Check the* Following -Pri Pwr -RF Pwr Output -Modula-tion	Same	Same		-Pri Pwr -Modu-lation Input	None	No	No	No	No	None RF Pwr Out Same as S-Band PA	
	S-Band FM Transmitter Modem (Simular to Ku-Band FM Transmitter Modem + Voice Capability)	2	.	.	2	1	286K		No	Check the* Following -Pri Pwr -Modula-tion -Data On/Off -TV On/Off -TV Channel Selected	Same	Same		-Pri Pwr -Modu-lation Input A&D -Data Mode Control -TV Mode Control -TV Chan-nel Se-lect						None	

Subsystem R. F. Communications

Sheet 2

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
Ground Direct	S-Band PM Transponder Phase Detectors Subcarrier Demodulators Voltage Controlled Oscillator Auxiliary Oscillator Frequency Multipliers Phase Modulators	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR
	S-Band PM Transponder Modem Subcarrier Modulators Demodulators Amplifiers Filters	Same	Same	Same	Same	Same	Same	Same	Same
	S-Band Power Amplifier Traveling Wave Tube Amplifier Hi-Voltage Power Supply Control Circuitry	Electrical Interfaces EMI	Physical Dimensions of TWT Thermal Cooling Requirements Sensitivity to Power Supply Changes	Acceptable Parameter Levels R&R Procedures	None	R&R Tools Tethers	Recommend TWT & Pwr Supply be Mated and Adjusted on the Ground	Good Voltage Regulation on Power Input	Design for TWT Replacement in Orbit
	S-Band FM Exciter 47.5 mHz Local Oscillator FM Modulator Frequency Multipliers Amplifiers Filters Power Supply	Same as S-Band RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR	Same as S-Band Video RCVR
	S-Band FM Transmitter Modem (Similar to Ku-Band FM Transmitter Modem + Voice Capability)	Same	Same	Same	Same	Same	Same	Same	Same

Subsystem R. F. Communications

Sheet 1

1 Group	2 LRU/SRA	3 Quantity Required	Redundant	Spares	Total	4 No. of Books	5 MTBF (Hrs)	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On-Line)	9 Manual Fault Isolation Req's (On-Line)	10 Operational Recovery Scheme	11 MTTR (Hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustments	14 Calibration Req's Pre-Installation	Periodic	Manual	Automatic	15 Margin Check Requirements Trend Analysis	16 Hazards
	VHF Transceiver (Voice/Ranging) Crystal Oscillators Frequency Multipliers Amplifiers Mixers FM Modulator FM Detector	2	·	·	2	2 ea. 4 Wide	642K		No	Check the* Following •Pri Pwr •RF Pwr Output Level •VSWR •Modulation Output •AGC Level	Monitor Stimulus Responses	Use Functionally Redundant System		•Pri Pwr Control •Modulation Input A&D •AGC	None	No	No	No	No	None RF Pwr Output Level Sample 1/Minute compare with Average of Last 48 Samples - Retain Daily Average for 3 Months Trend Analysis - Sample AGC Stimulus and Response 1/Day Compare with Average of 30 Previous Samples	
	VHF Voice Tranceiver Modem Fixed Frequency Tel Transceiver Range Gate	2	·	·	2	1 2 Wide	234K		No	•Pri Pwr* •Voice Mode •Squelch Override/Enable •Ranging On/Off •Modulation Output	Monitor Stimulus Responses	Use Functionally Redundant System		•Pri Pwr •Voice Mode •Squelch Control •Ranging Mode •Modulation Input	None	No	No	No	No	None None	
	Ranging Modem Pseudo-Random Code Generation Code Correlation Detector Clock Oscillator Phase Detector Range/Range Rate Counters	2	·	·	2	1 9 Wide	225K		No	Check the Following* •Pri Pwr •Shuttle Range On/Off •FFM Range On/Off •FFM Rcvr Selected •Code Correlation Lock •Range Data & Modulation	Same	Same		•Pri Pwr •Shuttle Ranging •FFM Ranging Control •FFM RCVR Selected •Range Code	None	No	No	No	No	None None	
	VHF Data Tranceiver	2	·	·	2	2	642K		No												
	(SIMILAR TO THE VHF VOICE/RANGING T/R WITH EXCEPTION THAT THE FRM MODULATOR IS REPLACED BY A PHASE MODULATOR)																				
	VHF FM Tranceiver Oscilator Frequency Multipliers Mixers Filters Frequency Modulator FM Detector	6	·	·	6	1 3 Wide	642K		No	Check the Following* •Pri Pwr •RF Pwr Out •VSWR •Modulation Output •AGC Output	Same	Same		•Pri Pwr •Modulation Input •AGC	None	No	No	No	No	None RF Pwr Out AGC Level Same as VHF Transceiver	
	VHF FM/TR Modem Fixed Frequency Tel Transceiver Biomedical Filters Biomedical Amplifiers Biomedical Detectors	2	·	·	2	1 4 Wide	384K		No	•Pri Pwr * •Modulation Output •Voice On/Off •Biomed On/Off •Squelch Enable Override •Vox Enable Override	Same	Same		•Pri Pwr •Modulation Input •Voice Mode •Biomed Mode •Squelch •Vox Mode	None	No	No	No	No	None None	
	*DMS Controlled																				

Subsystem R. F. Communications

Sheet 2

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
Shuttle	VHF Transceiver (Voice/Ranging) Crystal Oscillators Frequency Multipliers Amplifiers Mixers FM Modulator FM Detector	•Electrical Interface •EMI	•Tuning •Tolerance Build-up	•Knowledge of Normal Levels and Allowable Tolerances •R&R Procedures	•Tuning & Alignment Procedures	•R&R Tools •Tethers	•Audio Osc. •VTUM •VHF Freq. Meter •Attenuator Box •Screened Room •Electrical Interfaces	None	•Part Interchangeability •Part commonality •Test Point Accessibility & Buffering •Minimize Human Error •Cooling Requirements
	VHF Voice Tranceiver Modem Fixed Frequency Tel Transceiver Range Gate	Same	Same	Same	Same	Same	Same	None	Same
	Ranging Modem Pseudo Random Code Generator Code Correlation Detector Clock Oscillator Phase Detector Range/Range Date Counters	Same	Same	Same	Same	Same	•Frequency Counter •Timing Generator •Spectrum Analyzer •Electrical Interfaces	None	Same
	VHF Transceiver	Same	Same	Same	Same	Same	Same as VHF Transceiver	None	Same
EVA	VHF FM Transceiver Oscillator Frequency Multipliers Mixers Filters Frequency Modulator FM Detector	Same	Same	Same	Same	Same	Same	Same	Same
	VHF FM T/R Modem Fixed Frequency Tel Transceiver Biomedical Filters Biomedical Amplifiers Biomedical Detectors	Same	Same	Same	Same	Same	Same	Same	Same

Subsystem R. F. Communications

Sheet 1

1 Group	2 LRU/SRA	3 Quantity Required	3 Quantity Redundant	3 Quantity Spares	3 Quantity Total	4 No. of Books	5 MTBF (Hrs)	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On-Line)	9 Manual Fault Isolation Req's (On-Line)	10 Operational Recovery Scheme	11 MTTR (Hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustments	14 Calibration Req's Pre Installation	14 Calibration Req's Periodic	14 Calibration Req's Manual	14 Calibration Req's Automatic	15 Margin Check Requirements Trend Analysis	16 Hazards
High Gain Antenna	(Transmit)																				
	Ku-Band Quadriplexor	4	-	-	4	N/A	175K		No	No Data	No Data	Use Func-		No Data	No	No	No	No	No	None	(IVA)
	Circulator	4	-	-	4	N/A	175K		No	No Data	No Data	tionally		No Data	-	-	-	-	-	None	Total
	RF Switches	5	-	-	5	N/A	175K		No	No Data	No Data	Redundant		No Data	-	-	-	-	-		Quan-
	Ku-Band Diplexor	1	-	-	1	N/A	175K		No	No Data	No Data	System		No Data	-	-	-	-	-		tity
																					Non-
																					Criti-
																					cal
	(Receive)																				
	S-Band Quadriplexor	4	-	-	4	N/A	175K		No	No Data	No Data	Same		No Data	No	No	No	No	No	None	(IVA)
	RF Switches	3	-	-	3	N/A	175K		No	No Data	No Data			No Data	-	-	-	-	-	None	Same
	Power Divider	4	-	-	4	N/A	175K		No	No Data	No Data			No Data	-	-	-	-	-		
	S-Band Diplexor	1	-	-	1	N/A	175K		No	No Data	No Data			No Data	-	-	-	-	-		
	(Antenna Boom)									Check the											
	Tunnel Diode Amp/Mixer/									Following*											
	L.O.	8	8	-	16	N/A	175K		Yes	·Pri Pwr	None	For Yes in		·Pri Pwr	No	No	No	No	No	None	(EVA)
	Main Reflector & Feed	4	-	-	4	N/A	175K		No	·Preamp		Col. 7, switch		·Select	Yes	-	-	-	-	None	3-Hour
	Acquisition Reflector									Selected		to Redun-		Control							Limit
	and Feed	4	-	-	4	N/A	175K		No	·Preamp		dant Assem-		·RF Input	No	-	-	-	-		on LSS
	Pseudo-Monopulse									Output		bly, then									Total
	Comparator	8	8	-	16	N/A	175K		Yes	Level		R&R to		·Antenna	No	-	-	-	-		Quan-
	RF Switches	2	-	-	2	N/A	175K		No	·Antenna		Restore		Select	No	-	-	-	-		tity
	Diplexors					N/A	175K		No	Selected		Redundancy		Control	No	-	-	-	-		Not
	Couplers					N/A	175K		No	·Feed RF		-----		·Antenna	No	-	-	-	-		Criti-
	Positioners					N/A	175K		No	Pwr Level		No-Use		Position	No	-	-	-	-		cal
	Drive Motors	8	-	-	8	N/A	175K		No	·Antenna		Functionally		Control	No	-	-	-	-		
	Drive System	8	-	-	8	N/A	175K		No	Position		Redundant		·Override	No	-	-	-	-		
	Electronics	8	8	-	16	N/A	175K		Yes	·Acq-Main		System till		Auto	No	-	-	-	-		
										Antenna		R&R can be		Control							
										Override/		Scheduled									
										Auto Se-											
										lected											
										·Feed											
										VSWR											
										Level											
	Ku-Band Wave Guide	4	-	-	4		175K		No	No Data	TBD	TBD		No Data	No	No	No	No	No	None	(EVA)
	S-Band Coaxial Cable	4	-	-	4		175K		No	No Data	TBD	TBD		No Data	No	No	No	No	No	None	Total
																					Quan-
																					tity
																					Not
																					Criti-
																					cal
	*DMS Control																				

Maintenance Requirements Analysis (Cont.)

Subsystem R. F. Communications

Sheet 2

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
High Gain Antenna	(Transmit) Ku-Band Quadriplexor Circulator RF Switches Ku-Band Diplexor	Electrical Interfaces EMI VSWR Fault Isolation	None	R&R Instruction	None	R&R Tools	None Mechanical Assemblies	None	None
	(Receive) S-Band Quadriplexor RF Switches Power Divider S-Band Diplexor	Same	None	Same	None	None	Same	None	Same
	(Antenna Boom) •Tunnel Diode Amp/ Mixer/L.O. Main Reflector & Feed Acquisition Reflector and Feed •Pseudo Monopulse Comparator RF Switches Diplexors Couplers Positioners Drive Motors Drive System •Electronics	·Space Suit ·R&R Activity	·EMI• ·Alignment ·Tolerance Build-up Other LRU's Predominantly Mechanical not Bench Repairable	·Fault Isolate to-LRU ·R&R Instructions ·Procedure for Adjusting Insertion Loss	·Alignment • Procedures ·Repair Procecures ·Verification Procedures	Wrenches Tethers Space Suit Hand Holds Body Restraints	· Signal Source • · Load · VTUM · Spectrum Analyzer None - (Mechanical) None - (Mechanical)	Provide Umbilical Connection in area where EVA is to be Performed Design LRU's for ease of Replacement Under EVA Conditions	·Part Interchangeability ·Part Commonality ·Test Point Accessibility and Buffering ·Simplify Procedures ·Minimize Human Error
	Ku-Band Wave Guide S-Band Coaxial Cable	Same	None	R&R Instruction	None	R&R Tools	None Coax Repair Tools	None	None

Maintenance Requirements Analysis (Cont.)

Subsystem R. F. Communications

Sheet 1

1 Group	2 LRU/SRA	3 Quantity Required	3 Quantity Redundant	3 Quantity Spares	3 Quantity Total	4 No. of Books	5 MTBF (Hrs)	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On Line)	9 Manual Fault Isolation Req's (On Line)	10 Operational Recovery Scheme	11 MTTR (Hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustment	14 Calibration Req's Pre-Installation	14 Calibration Req's Periodic	14 Calibration Req's Manual	14 Calibration Req's Automatic	15 Margin Check Requirements Trend Analysis	16 Hazards
	Ku-Band Wave Guide	8	-	-	8	N/A	?		No	Monitor* VSWR	None	Use Parallel System		None	None	No	No	No	No	None	EVA Req'd on that portion external to vehicle
	VHF/S-Band Coaxial Cable	8	-	-	8	N/A	?		No	Monitor* VSWR	None	Use Parallel System		None	None	No	No	No	No	None	Same
	Antenna, S-Band	4	-	-	4	N/A	2780 K		No	Check the Following* ·Antenna Select ·RF Pwr ·VSWR		Use Parallel System		·Antenna Select Control	Yes	No	No	No	No	None	EVA
	Triplexer	2	-	-	2	N/A	-		No						Yes	No	No	No	No		
	RF Switched	2	-	-	2	N/A	-		No						Yes	No	No	No	No		
	Antenna, VHF	4	-	-	4	N/A	2780 K		No	Check the Following* ·Antenna Selected ·RF Pwr ·VSWR		Same		·Antenna Select Control	Yes	No	No	No	No	None	EVA
	Diplexer	4	-	-	4	N/A			No						Yes	No	No	No	No		
	2 Channel Multiplexer	2	-	-	2	N/A			No						Yes	No	No	No	No		
	Power Divider	2	-	-	2	N/A			No						Yes	No	No	No	No		
	4 Channel Multiplexer	2	-	-	2	N/A			No						Yes	No	No	No	No		
	RF Switches	2	-	-	2	N/A			No						Yes	No	No	No	No		
	Antenna, Ku-Band	8	-	-	8	N/A	2780 K		No	Check the Following* ·Pri Pwr On/Off ·Preamp-Mixer-L.O. Output ·Antenna Selected ·RF Pwr ·VSWR		Same		·Pri Pwr Control ·RF Input ·Antenna Select Control	Yes	No	No	No	No	None	EVA
	RF Switches	2	-	-	2	N/A			No						Yes	No	No	No	No		
	Diplexer	2	-	-	2	N/A			No						Yes	No	No	No	No		
	Tunnel Diode Amplifier	2	-	-	2	N/A			No						Yes	No	No	No	No		
	Mixer	2	-	-	2	N/A			No						Yes	No	No	No	No		
	Oscillator	2	-	-	2	N/A			No						Yes	No	No	No	No		
	Circulator	2	-	-	2	N/A			No						Yes	No	No	No	No		
	10 Channel S-Band Multiplexer	2	-	-	2	N/A			No						Yes	No	No	No	No		

*DMS Control

Subsystem R. F. Communications

Sheet 2

1	2	17		18				19	
		Problems		Maintenance Requirements				Design/SRT Requirements	
				Software		Tools Test Equipment-Facilities			
Group	LRU/SRA	Inplace (Off-Line) Control or Experiment Complex	Bench (Central)	Inplace	Bench	Inplace	Bench	Inplace	Bench
Low Gain Antenna	Ku-Band Wave Guide	R&R in EVA Environment	None	R&R Procedure	None	R&R Tool Kit	None	Design Wave Guide for Quick Change	None
	VHF/S-Band Coaxial Cable	Same	None	R&R Procedure Instructions	Cable Repair	R&R Tool Kit	Connector Kit for Replacement	None	None
	Antenna, S-Band Triplexer RF Switches	Same as Wave Guide	Tolerance Build-up	Same + Procedure for Adjusting Insertion Loss	Maintenance Instructions	Same	Tool Kit Attachment Device	Manually Operated Quick Disconnect	Accessability
	Antenna, VHF 2 Channel Multiplexer Power Divider 4 Channel Multiplexer RF Switches	Same	Same	Same	Same	Same	Tool Kit Attachment Device	Same	Same
	Antenna, Ku-Band RF Switch Diplexer Tunnel Diode Amplifier Mixer Oscillator Circulator 10 Channel S-Band Multiplexer	Same	Same	Same	Same	Same	Tool Kit Attachment Device	Same	Same

Subsystem Guidance, Navigation & Control

Sheet 1

1 Group	2 LRU/SRA	3 Quantity: Required	3 Quantity: Redundant	3 Quantity: Spares	3 Quantity: Total	4 No. of Books	5 MTBF (Hrs)	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On-Line)	9 Manual Fault Isolation Req's (On-Line)	10 Operational Recovery Scheme	11 MTTR (Hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustments	14 Calibration Req's: Pre-Installation	14 Calibration Req's: Periodic	14 Calibration Req's: Manual	14 Calibration Req's: Automatic	15 Margin Check Requirements Trend Analysis	16 Hazards
Attitude Reference	Gyro	3	3	-	6	N/A	50K		No	Enter FI Routine	None	Auto Switch to Redundant Element - R&R Restore Redundancy		Torque Commands Mode Commands	No	No	No	No	No	None	None
	Gyro Electronic Assembly	3	3	-	6	½	50K		No						No	-	-	-	Yes	Monitor Case Temp. Integrate & Compare to Limit and HTR Voltage	
	Gyro Power Supply	1	1	-	2	?	50K		No						No	No	No	No	No		
	Horizon Sensor (4HDS)	1	-	-	1	N/A	150K		No	Enter FI Routine	None	None Fail Soft		Mode Command	No	No	No	No	No	None None	None
	Horizon Detector	2	-	-	2	N/A	100K		No	Enter FI Routine	Respond to 'Unable to Isolate' Message	None		Mode Command Monitor Normal & Stimulate Outputs	No					None	None
	Star Sensor (2HDS)	1	-	-	1	N/A	35K		No	Enter FI Routine	None	None		Mode Command Detector Output						None	None
	Star Tracker	2	1	-	3	N/A	21K		Yes	Enter FI Routine	None			Gimbal Mode Commands Simulated Output	No	-	-	-	Yes	None	None
	Star Tracker Electronics	2	1	-	3	10	21K		Yes						No	-	-	-	Yes	None	None
	Alignment Monitor (Sensor)									Perform Periodic Checkout 1per Month or after Docking	Isolate Problem then R&R			Electronic Stimuli & Mode Command							
	Signal Transmitter	2	-	1	3	N/A	100K		No			None			No	No	No	No	No	None	None
	Signal Receiver	2	-	1	3	N/A	100K		No							No	No	No	No	None	
	Alignment Monitor (Experiment)													Electronic Stimuli and Mode Command							
	Target Alignment Transmitter	2	-	1	3	N/A	100K		No	Same as Above	Same as Above	None			No	No	No	No	No	None	
	Target Sensor System	2	-	1	3	N/A	100K		No						?	No	No	No	No	None	
	Prism Alignment Transmitter	2	-	1	3	N/A	100K		No						No	No	No	No	No		None
	Light Deflecting Patterns	2	-	1	3	N/A	100K		No						?	No	No	No	No		
Navigation	Low-G Accelerometer	1	1	-	2	N/A	358K		Yes	Monitor Rebalance Signal-HTR Voltage Simulated Output	Same as Above	Auto Switch to Redundant Element		Mode Command	No	No	No	No	No	None	None
	Accelerometer Electronics	1	1	-	2	N/A	358K		Yes						No	No	No	No	No	Monitor Temp 10 min α $T_{at} \leq$ Limit α HTR Voltage	

NOTE: INSUFFICIENT TIME & DATA TO COMPLETE SHEET 2

Subsystem Guidance, Navigation & Control

Sheet 1

1 Group	2 LRU/SRA	3 Quantity: Required	Redundant	Spares	Total	4 No. of Books	5 MTBF (Hrs)	6 Critical Downtime Limit	7 Software Reconfigurable	8 Fault Isolation Scheme (On-Line)	9 Manual Fault Isolation Req's (On-Line)	10 Operational Recovery Scheme	11 MTTR (hrs)	12 Self Test or Stimulus Req's	13 Mechanical Adjustments	14 Calibration Req's: Pre-Installation	Periodic	Manual	Automatic	15 Manual Fault Isolation Req's (On-Line)	16 Hazards
Navigation (Cont)	Landmark Tracker	1	1	-	2	N/A	100K		Yes	Monitor Encoder and Detector Outputs	Same as Above	Auto Switch to Redundant Element		Gimbal Commands Simulated Detector Output Mode Command	No	-	-	-	Yes	None	None
	Tracker Electronics	1	1	-	2	10	100K		Yes						No	No	No	No	No	None	
	Interface Electronics													Buffer Control Buffer Address Buffer Reset Control Address Reset							
	Inertial Sensor Buffer	2	2		4	¼	61K		Yes	Tested as Part Other FI Routines	None	Same			No	No	No	No	No	None	None
	Horizon Sensor Buffer	1	1		2	¼	61K		Yes						No	No	No	No	No	None	
	Stellar Sensor Buffer	1	1		2	¼	61K		Yes						No	No	No	No	No		
	Landmark Alignment Buffer	1	1		2	¼	61K		Yes						No	No	No	No	No		
	Laser Tracker Buffer	2	2		4	¼	61K		Yes						No	No	No	No	No		
	CMG Control	4	4		8	¼	61K		Yes						No	No	No	No	No		
	Reaction Jet Control	2	2		4	¼	61K		Yes						No	No	No	No	No		
	Data Control Buffer	4	4		8	¼	61K		Yes						No	No	No	No	No		
Rendezvous and Tracking	Laser Docking Tracker	7	-	-	7	N/A	100K		No	Periodic Check out Before Use	Monitor Tracker Outputs and Received Energy Level	Use Another Docking Port		Electronic Stimuli & Mode						None	None
	LDT Electronics	7	-	-	7	16	100K		No											Sample Xmitter Pwr & Rcvr Energy Compare to Samples	
	Laser Rendezvous Tracker	2	-	2	4	N/A	100K		No	Enter FI Routine	None	None		Gimbal Command Elec. Stimuli Command						None	
	LRT Electronics	2	-	2	4	16	100K		No			R&R								Xmitter Pwr Rcvr Energy Compare to Average of 10 Samples	
Control	Reaction Jet Control Electrical Assembly									Periodic Check Out	Monitor Checkout Results	None		Driver Inputs Reset Mode Command						None Jet Driver Input-Log Daily Firings	
	High Thrust Jet Driver	1	-	1	2		1430K		Yes						No	No	No	No	No		None
	Resistojet Control Module	1	·	1	2		1430K		Degraded						No	No	No	No	No		
	Backup Control Electronics	1	-	1	2		1430K								No	No	No	No	No		
	CMG Rotor/Gimbal	4	2	-	6		200K		Yes					None	No	No	No	No	No	None	Mass
	CMG Torquer (Inner)	4	2	-	6		200K		Yes					None		-	-	-	Yes	Sample Following Signals	
	CMG Torquer (Outer)	4	2	-	6		200K		Yes					None		-	-	-	Yes		
	Rotor Control Electronics	4	2	-	6		100K		Yes					None	No	No	No	No	No	Spin Pwr Vibration Bearing Temperature Vacuum	None
	Torquer Control Electronics	4	2	-	6		100K		Yes					Mode Command	No	No	No	No	No		

APPENDIX B

ON LINE MAINTENANCE TRADE DATA CHARTS

ON LINE MAINTENANCE TRADE DATA

SUBSYSTEM Data Management

GROUP LRU	Fault Isolate to LRU R&R	Fault Isolate to LIU Manual FI to LRU then R&R	FI Manually Initiated and Monitored R&R the LRU	Number of LRU's
COMPUTER GROUP				
Data Bus Controller	X			
Data Bus Switch Matrix		X		
Memory Switch Matrix		X		
Data Bus I/O		X		
Shared Memory I/O		X		
CPU Logic and Control	X			
Dedicated Memory	X			
CPU Power Supply	X			
Shared Memory Electronics Section	X			
Shared Memory Mechanical Assembly			X	
Memory Elements	X			
Shared Memory Power Supply	X			
Totals	7	4	1	12
BULK DATA STORAGE				
Data Bus Terminal	X			
Digital Buffer and Control	X			
Record/Reproduce Electronics Assembly	X			
Transport Switch Matrix	X			
Controller Switch Matrix	X			
Tape Transports			X	
Tape Transport Controllers	X			
Bulk Data Storage Power Supply	X			
Totals	7	0	1	8

ON LINE MAINTENANCE TRADE DATA (Continued)

SUBSYSTEM Data Management GROUP LRU	Fault Isolate to LRU R&R	Fault Isolate to LIU Manual FI to LRU then R&R	FI Manually Initiated and Monitored R&R the LRU	Number of LRU's
DATA ACQUISITION				
Data Bus Terminal	X			
RDAU (or LMDU)	X			
Stimuli Generation Unit	X			
Totals	3	0	0	3
COMMAND/CONTROLS AND DISPLAY				
Data Bus Terminal	X			
Display Control & Buffer	X			
Display Switch Matrix	X			
Refresh Buffer	X			
Display Control	X			
CRT Display Assembly			X	
Warning Annunciator Assembly			X	
Caution Display Assembly			X	
Alpha-Numeric Display Assembly			X	
Status Light Assembly			X	
Dedicated Displays			X	
Command Buffer & Control	X			
Digital Multiplexer	X			
Hand Controller Assembly			X	
Computer Keyboard Assembly			X	
Mode Select Switch Assembly			X	
Multifunction Switch Assembly			X	

ON LINE MAINTENANCE TRADE DATA (Continued)

SUBSYSTEM Data Management GROUP LRU	Fault Isolate to LRU R&R	Fault Isolate to LIU Manual FI to LRU then R&R	FI Manually Initiated and Monitored R&R the LRU	Number of LRU's
COMMAND/CONTROLS AND DISPLAYS (Continued)				
Mono-Function Switch Assembly			X	
Discrete Controls			X	
Microfilm Viewer Assembly			X	
Microfilm Viewer Control and File			X	
Analog Interface Unit			X	
Channel Select & Analog Control			X	
CCTV Panel Assembly			X	
Intercom Control Panel Assembly			X	
Audio Tape Assembly			X	
Video Tape Assembly			X	
Illumination Control Assembly			X	
CCDC Power Supplies			X	
Totals	7	0	22	29
PORTABLE DISPLAY AND CONTROLS				
Data Bus Terminal	X			
Display Assembly			X	
Computer Keyboard Assembly			X	
Optional Pluggable Functions			X	
Power Supply			X	
Totals	1	0	4	5

ON LINE MAINTENANCE TRADE DATA (Continued)

SUBSYSTEM Data Management

GROUP LRU	Fault Isolate to LRU R&R	Fault Isolate to LIU Manual FI to LRU then R&R	FI Manually Initiated and Monitored R&R the LRU	Number of LRU's
GN&C PREPROCESSOR				
Data Bus Terminal	X			
GN&C Preprocessor	X			
Totals	2	0	0	2
ATTITUDE REFERENCE				
Gyro	X			
Gyro Electronics	X			
Gyro Power Supply	X			
Horizon Sensor (4 Hds)	X			
Horizon Detector		X		
Star Sensor (2 Hds)	X			
Star Tracker	X			
Star Tracker Electronics	X			
Sensor Alignment Monitor Transmitter			X	
Sensor Alignment Monitor Receiver			X	
Experiment Target Alignment Transmitter			X	
Experiment Target Sensor System			X	
Experiment Prism Alignment Transmitter			X	
Experiment Light Deflecting Platforms			X	
Totals	7	1	6	14

ON LINE MAINTENANCE TRADE DATA (Continued)

SUBSYSTEM Guidance, Navigation & Control GROUP LRU	Fault Isolate to LRU R&R	Fault Isolate to LIU Manual FI to LRU then R&R	FI Manually Initiated and Monitored R&R the LRU	Number of LRU's
NAVIGATION				
Low-G Accelerometer	X			
Low-G Accelerometer Electronics	X			
Landmark Tracker	X			
Landmark Tracker Electronics	X			
Inertial Sensor Buffer	X			
Horizon Sensor Buffer	X			
Stellar Sensor Buffer	X			
Landmark Alignment Buffer	X			
Laser Tracker Buffer	X			
CMG Control Buffer	X			
Reaction Jet Control Buffer	X			
Data Control Buffer	X			
Totals	12	0	0	12
RENDEZVOUS AND TRACKING				
Laser Docking Tracker	X			
Laser Docking Tracker Electronics	X			
Laser Rendezvous Tracker	X			
Laser Rendezvous Tracker Electronics	X			
Totals	4	0	0	4

ON LINE MAINTENANCE TRADE DATA (Continued)

SUBSYSTEM Guidance, Navigation & Control GROUP LRU	Fault Isolate to LRU R&R	Fault Isolate to LIU Manual FI to LRU then R&R	FI Manually Initiated and Monitored R&R the LRU	Number of LRU's
CONTROL				
Reaction Jet Thrust Driver	X			
Resis-to-Jet Control Module	X			
Backup Control Modules	X			
Backup Control Electronics	X			
CMG Rotor/Gimbal	X			
CMG Torquer (Inner)	X			
CMG Torquer (Outer)	X			
Retor Control Electronics	X			
Torquer Control Electronics	X			
Totals	9	0	0	9
TOTALS	32	1	6	39

ON LINE MAINTENANCE TRADE DATA (Continued)

Preliminary Data W/O Benefit of Task 2				
SUBSYSTEM R. F. Communications GROUP LRU	Fault Isolate to LRU R&R	Fault Isolate to LIU Manual FI to LRU then R&R	FI Manually Initiated and Monitored R&R the LRU	Number of LRU's
FFM				
S-Band Video Receiver	X			
Video Receiver Modem	X			
S-Band Data Receiver	X			
DRSS				
S-Band PM Receiver	X			
K_u-Band FM Exciter	X			
FM Xmtr Modem	X			
S-Band FM Receiver	X			
Receiver Modem	X			
FFM-DRSS COMMON				
K_u-Band PA	X			
K_u-Band PM Exciter	X			
GROUND DIRECT				
S-Band PM Transponder	X			
Transponder Modem	X			
S-Band Power Amp	X			
S-Band FM Exciter	X			
Transmitter Modem	X			

ON LINE MAINTENANCE TRADE DATA (Continued)

Preliminary Data W/O Benefit of Task 2

SUBSYSTEM R. F. Communications GROUP LRU	Fault Isolate to LRU R&R	Fault Isolate to LIU Manual FI to LRU then R&R	FI Manually Initiated and Monitored R&R the LRU	Number of LRU's
SHUTTLE				
VHF Voice Ranging T/R	X			
Ranging Modem	X			
Voice Modem	X			
VHF Data T/R	S			
EVA				
VHF - FM T/R	X			
Modem	X			
Totals	21	0	0	21
LOW-GAIN ANTENNA GROUP				
VHF Antennas		X		
VHF Diplexers		X		
VHF Multiplexer, Power Dividers & Switches				
S-Band Antennas		X		
S-Band Triplexer and Switches	X			
K_u-Band Antennas		X		
K_u-Band Preamp/Mixer/Diplexer/Switches	X			
S-Band Multiplexer and Circulator	X			
K_u-Band Waveguides		X		
VHF/S-Band Coaxial Cables		X		
Totals	3	7	0	10

ON LINE MAINTENANCE TRADE DATA (Continued)

Preliminary Data W/O Benefit of Task 2

SUBSYSTEM R. F. Communications GROUP LRU	Fault Isolate to LRU R&R	Fault Isolate to LIU Manual FI to LRU then R&R	FI Manually Initiated and Monitored R&R then LRU	Number of LRU's
HIGH-GAIN ANTENNA GROUP				
Main Reflector/Feed		X		
Acq. Reflector/Feed		X		
Pseudo Monopulse Comp/Mod.		X		
Positioner		X		
Drive Motors		X		
Drive System		X		
Electronics		X		
K_u-Band TDA/Mixer/ L.O.	X			
RF Switches (External)	X			
RF Switches (Internal)	X			
K_u-Band Quadriplexers and Circulators		X		
K_u-Band Diplexer		X		
S-Band Quadriplexers and Power Divider		X		
S-Band Diplexer		X		
K_u-Band Waveguides		X		
S-Band Coaxial Cable		X		
Totals	3	12	0	15

ON LINE MAINTENANCE TRADE DATA SUMMARY

Subsystem Group	No. of LRU's Considered	LRU's Requiring Manual Initiation or Assistance to Fault Isolate	Percent of LRU's Requiring Manual Assistance
Data Management			
Computer	12	5	42
Bulk Data Storage	8	1	12
Data Acquisition	3	0	0
Command/Control and Display	29	22	76
Portable Display	5	4	80
GN&C Preprocessor	2	0	0
Total	59	32	54
GN&C			
Attitude Reference	14	7	50
Navigation	12	0	0
Rendezvous & Tracking	4	0	0
Control	9	0	0
Total	39	7	18
RFCS			
T/R/Modem	21	0	0
Low-Gain Antenna	10	7	70
High-Gain Antenna	15	12	80
Total	46	19	41
GRAND TOTAL	144	58	40

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